JOURNAL OF THE A·I·E·E·

MARCH — 1929

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MEETINGS

of the

American Institute of Electrical Engineers

REGIONAL MEETING, Middle Eastern District No. 2, Cincinnati, Ohio, March 20-22, 1929

REGIONAL MEETING, South West District No. 7, Dallas, Texas, May 7-9, 1929

SUMMER CONVENTION, Swampscott, Mass., June 24-28, 1929

PACIFIC COAST CONVENTION, Santa Monica, Calif., September 3-6, 1929

REGIONAL MEETING, Great Lakes District No. 5, Chicago, Illinois, December 2-4, 1929

For future A. I. E. E. Section Meetings see page 244.

MEETINGS OF OTHER SOCIETIES

National Electric Light Association

Iowa Section-Operators' Section, Sioux City, Feb. 26-27. (H. E. Weeks, Davenport, Ia.)

Middle West Division, Hotel Fontenelle, Omaha, Neb., April 24-26 (T. A. Browne, Lincoln, Neb.)

Southwestern Division, Arlington Hotel, Hot Springs, Ark., April 30-May 3 (S. J. Ballinger, San Antonio Public Service Co., San Antonio, Texas)

The American Society of Mechanical Engineers, Knoxville, Tenn., March 21-23 (C. W. Rice, 29 West 39th St., New York, N. Y.)

American Electrochemical Society, Toronto, May 27-29. C. G. Fink, Columbia, University, New York

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JOURNAL OF THE A. I. E. E.

DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

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Vol. XLVIII MARCH, 1929 Number 3

IT IS generally conceded that the very rapid advance in improvement of living conditions in the civilized world is largely the result of engineering achievement. This fact places on the engineer an obligation of leadership in the affairs of his nation and of the world—a new leadership, but one in which his trained analytical mind should well serve him.

Is he accepting this leadership?

There are outstanding examples of such acceptance, the most notable, of course, being Herbert Hoover. But how general is this among the rank and file of the profession? Unfortunately we find instances that indicate a leaning toward what psychologists call an "inferiority complex" in otherwise far-visioned engineers.

In a recent discussion of some problems of public interest a very prominent engineer said, "I think engineers ought to stay out of that sort of thing." Fortunately he was alone in this thought among a large number of engineers. Another engineer of very wide contacts reporting for a small group indicated that a certain problem could not be taken care of by engineers alone, the implication being that this was because it involved certain economic and commercial considerations; yet a very similar problem had been successfully solved by another group of engineers a few years back. In fact no engineering solution is complete until the economic and usually also the commercial phases have been considered. The prominence and the long experience of these particular engineers may indicate that there are others who think likewise and this gives rise to the question in the preceding paragraph.

It is certain that the public will not rank engineers any higher than they rank themselves.

What can the Institute do to bring about a better and truer and more universal appreciation of the profession by the engineer himself? We all have our ideas about things to do looking toward this end. I would urge a discussion of the subject in every Section as part of the program of an early meeting. No doubt valuable suggestions will come out of such discussions, and when these are sent in to headquarters office they will form an interesting guide for some lines of important section activities.

R. F. Schuchardt

President.

Some Leaders of the A. I. E. E.

Morgan Brooks, Professor of Electrical Engineering at the University of Illinois and Fellow of the Institute since 1913, was born in Boston March 12, 1861. After graduating from Brown University in 1881, he expressed a desire to study engineering, but was opposed by his father, a lawyer, whose ambition it was that his son follow in his footsteps. Finding his son quite determined, however, Mr. Brooks demanded a "brief" substantiating the boy's claim to a right to digress from law and study engineering, and this brief, produced by dint of much effort, was sufficiently forceful to convince his father of his earnestness of purpose and secure the coveted permission, as well as strengthen his own determination to make a success. He was graduated from Stevens Institute in 1883; his thesis on the gas engine was published in the *Van Nostrand Magazine* and copied in translation in Paris and Berlin. After a short engagement involving gas engine installation, he accepted an appointment with the American Bell Telephone Company in Boston for research work. In this connection, he was wire inspector for the 7000 miles of wire in the line between New York and Philadelphia,—the first commercial long distance line of copper wire to be established. He also made all necessary electrical tests on the experimental telephone copper circuit between Boston and New York which served to determine many of the early problems of long distance telephony. In 1886 he resigned from the American Bell Telephone Company to become installation engineer in Boston for the Electric Storage Battery Company. In 1887 he was made secretary-treasurer of the St. Paul (Minn.) Gas Light Company. Here his first assignment was to investigate the Westinghouse a-c. system in competition with the d-c. system of the St. Paul Edison Company. Upon Mr. Brooks' recommendation the Westinghouse system of lighting was installed in St. Paul—one of the earliest plants in western territory.

In 1890 Mr. Brooks organized the Electrical Engineering & Supply Company of St. Paul and Minneapolis, and beside conducting an independent telephone business was engaged in isolated and municipal power plant installation. Among these activities might be mentioned a complete plant at Deer Lodge, Montana, and an independent telephone exchange at Northfield, Minn., using his own patents for an automatic system in competition with the then young Strowger system. In 1898, while retaining financial control of the above named company, Mr. Brooks accepted the professorship in electrical engineering at the University of Nebraska in charge of the department. Three years later he was appointed to a similar position at the University of Illinois, which he has occupied continuously ever since. Under his régime, the department grew to ten times its original size.

Being greatly interested in automatic synchronizing of alternators, Professor Brooks developed self-synchronizing by means of coreless inductance coils, now known as reactors. Through the courtesy of the Commonwealth Edison Company, the method was demonstrated in Chicago, and has resulted in the extended use of coreless reactances in various ways. Following this he developed a semi-empirical formula for the calculation of inductance of coils without cores, reducing cumbersome and often approximate formulas to a single formula for all shapes of coils and deriving the most economical shape and dimensions of coils for a given performance. During the war, owing to the reduced number of engineering students, he taught elementary mathematics and carried on extensive experiments on a new form of airplane propeller, claiming that air propulsion was not correctly determined by screw action and that the then common use of propellers arranged in tandem was scientifically incorrect. Professor Brooks was one of the Institute's managers 1907-1910 and a vice-president 1910-1912. He is a Life Member of the American Society of Mechanical Engineers, a member of the Western Society of Engineers, and the Illuminating Engineering Society, and of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu, honorary engineering societies.

An Unofficial Patent Court

An unofficial patent court to lighten the burden of litigation, said to be sapping the resources of industry, is urged by Dr. Harrison E. Howe of Washington, editor of *Industrial and Engineering Chemistry,* journal of The American Chemical Society.

Dr. Howe declares that the extension of the idea of the judicial process to lay bodies is rapidly gaining ground, and that the nation's chemical manufacturers should act in the interest of science and invention and of the industries and the courts.

Baseball, the theater, and the motion picture industry, Dr. Howe points out, are advantageously employing such a form of self-government. The desirability of setting up a single Federal Patent Court has frequently been stressed, a progressive group within the American patent bar having worked for years without accomplishing this step.

The American Engineering Council, through its Patent Committee, of which Edwin J. Prindle, President of the New York Patent Law Association, is Chairman, and the Committee on Patents of the American Institute of Chemical Engineers are again taking up this proposal. Dr. Howe is treasurer of the American Engineering Council, on which he is the representative of the Institute of Chemical Engineers.

Anyone who comes into contact with a patent system is straightway impressed with the numerous ways in which both applications and granted patents can be used to obstruct, as well as to further, industrial progress.

"Industry is not disposed to urge many fundamental changes, but it certainly can do much toward lightening the burden of patent litigation."

Abridgment of

A New High-Accuracy Current Transformer

BY M. S. WILSON[1]

Associate, A. I. E. E.

Synopsis.—This paper is presented for the purpose of describing a new method of compensation, by the use of which the ratio and phase-angle errors of current transformers are materially reduced. There are several similar methods now in use, but these methods possess some undesirable features which are not present in the one described in this paper.

By the use of this new method, in which a portion of the secondary turns and an auxiliary short-circuited turn enclose a section of the magnetic circuit, the change in ratio and phase angle between light and full load is considerably reduced, resulting in more nearly approaching a constant ratio, and phase-angle characteristics for all values of load. In view of the demand for meter and transformer combinations which must operate satisfactorily over large ranges of current, this is a desirable feature.

The overload characteristics of the current transformer are not injured by the use of this method of reducing the transformer errors. The usual insulation between the primary and secondary can readily be maintained, and the use of this compensating feature does not in any way impair the strength of the transformer to withstand over-current shocks.

No changes in the physical dimension of the transformer are required by the application of this compensating method.

INTRODUCTION

As is quite well known, the ratio and phase-angle errors inherent in current transformers are due to the exciting current which is required to maintain the flux and supply the losses in the core. There is a number of methods by which these errors may be reduced or compensated for. The following are most commonly used and operate with varying degrees of effectiveness for the several conditions of burden, frequency, etc., to which the transformer may be subjected.

1. The changing of secondary turns. This does not affect the losses, but raises or lowers the ratio approximately the same amount for the different values of secondary current. It has no effect on the phase angle. This method, which is universally used, operates equally well under the various conditions mentioned above.

2. The use of a large number of ampere-turns, a large cross-section of core, or both. For a first approximation, the errors in a current transformer are inversely proportional to the square of the number of ampere-turns and to the cross-section of the magnetic circuit, assuming the mean length to remain constant. Therefore an increase in either or both of these factors will improve the operating characteristics of the transformer under all conditions. The use of these two methods, however, is limited by the physical dimensions of the transformer.

3. The use of a high-permeability low-loss steel.[2] By using a steel which has a higher permeability and lower losses than the ordinary transformer steel, the exciting current may be diminished, thus reducing the transformer errors. A material having these characteristics, however, usually saturates at quite low densities so that for moderate burdens or overload conditions the ratio and phase-angle errors increase very rapidly.

4. The use of the two-stage type of transformer.[3] This transformer is built in two stages, or cores. The function of the second stage is to supply a current which is equal in phase relation and magnitude to the exciting current required by the first stage. This type of transformer works well under any of the operating conditions to which it may be subjected. For power or energy measurements, however, somewhat special equipment is necessary.

5. The use of compensating shunts across the primary or secondary windings of the transformer. This method of correction operates satisfactorily only for fixed conditions of burden, frequency, etc..

6. A new method has recently been developed. When used in conjunction with the first method as described above, it furnishes a simple and effective means by which the ratio and phase-angle errors of current transformers are materially reduced. This type of correction operates in such a way as to effect an alteration of the flux conditions in the magnetic circuit, so that the product of the flux and secondary turns will vary in a direct proportion to the primary current.

This tends to produce a constant ratio between the primary and secondary currents for different percentages of load. The resulting constant error may then be reduced by the usual method of changing secondary turns.

In the new method of correction, the phase-angle errors of the current transformer are lessened by the use of a lag band on a section of the magnetic circuit. The function of this band is to lag the flux slightly, so as to throw the secondary current nearer in phase opposition to the primary current. The effect of this compensation varies with the percentage of load in

1. Engineering Department, General Electric Co., West Lynn, Mass.

2. *Current Transformers with Nickel-Iron Cores,* by Thomas Spooner, A. I. E. E. TRANS., 1926, p. 701.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

3. *Two-Stage Current Transformer,* by H. B. Brooks and F. C. Holtz, A. I. E. E. TRANS., 1922, p. 382.

such a way that a large correction is obtained in the light load region, where the errors are large, and a smaller correction as full load is approached, where the errors are less. This combination of ratio and phase-angle corrector operates well under the various conditions of burden, frequency, and load, as well as under various overload conditions. The transformer is also entirely standard in so far as the use of external

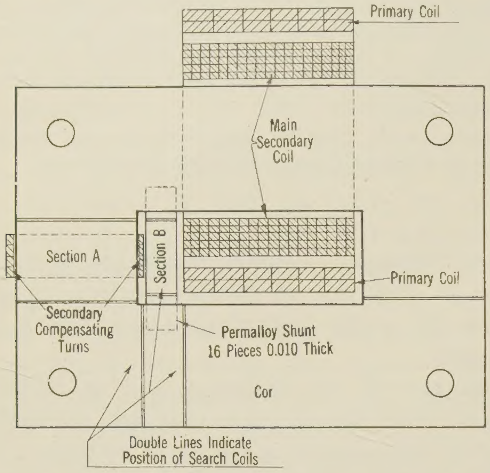

Fig. 1—Sectional View of a Current Transformer

Illustrating location of compensating turns and peramlloy shunt. Double lines indicate position of search coils

apparatus in either the primary or secondary circuits is concerned.

Details of the New Method of Reducing the Ratio and Phase-Angle Errors of Current Transformers

The principle upon which this new type of ratio corrector operates is, in effect, that of automatically

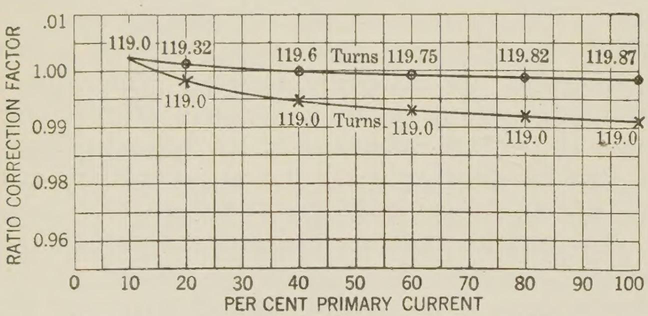

Fig. 2—Effect of Changing Partial Secondary Turns on a Current Transformer

x Standard transformer
● Compensated transformer

changing the effective secondary turns as the load increases or decreases.

For example, assume a ratio correction factor of 1.010 for 10 per cent load and of 1.000 for 100 per cent load. This indicates that at 10 per cent load, the secondary current will be one per cent too small and at 100 per cent load it will be correct. Therefore, if it were possible to increase the number of effective secondary turns by the proper amounts as the current increased from light load to full load, the ratio of the full-load point would be the same as that of the light-load point.

The resulting constant error, which in the case mentioned above would be one per cent, could then be eliminated by reducing the number of secondary turns one per cent.

In order to determine a method by which the effective secondary turns of a current transformer could be automatically changed for different load conditions, tests and calculations were made on a transformer in which the magnetic circuit and secondary turns were arranged as illustrated in Fig. 1. Here it will be noted that the secondary windings are arranged in two sections on the magnetic circuit, with the larger number of turns on the first or main section, and the remainder, usually one or two per cent of the total, on the second section. Since all of these turns are wound in the same direction, a correction in the ratio would be obtained if the flux could be shunted around

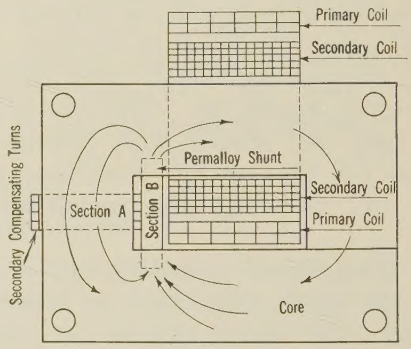

Fig. 3—Redistribution of Flux in Core of Compensated Current Transformer

the smaller number of turns for the lower values of secondary current and gradually caused to flow through them in the proper direction as the current increases. This would then have the effect of adding secondary turns as the current or load increased, which, in turn, would increase the ratio and straighten out the ratio curve. With the proper number of turns on both sections, the five-ampere or full-load point would have approximately the same ratio as the 0.5-ampere point. This is graphically illustrated in Fig. 2.

In order to afford a means by which the amount of flux linking the smaller number of turns could be altered, a shunt which was made up of permalloy strips, inserted as illustrated in Fig. 1, was employed. (Any material of low reluctance at low flux densities may be used for this shunt.)

The secondary turns around section *A* produce a magnetomotive force, the action of which is vital to the operation of this corrective method. This magnetomotive force causes a circulating flux, as illustrated in Fig. 3, which is superimposed on the main or primary flux in sections *A* and *B*. The result is a change in the relative flux densities of these two sections. Since the circulating flux varies with the secondary current, the relative flux densities in the two sections will also vary. This variation in density will cause a change

in the relative reluctances of the two sections so that at higher currents, the reluctance of section B will be considerably larger than that of section A, thus causing a relatively larger portion of the main flux to flow in the latter section.

Therefore, since the proportion of main or primary flux, linking the secondary turns on section A, increases with the secondary current, the desired effect of an increase in effective secondary turns will be produced. This tends to maintain a nearly constant ratio for different values of secondary current.

From the arrangement of the turns on section A, and the arrangement of the magnetic circuit, it is seen

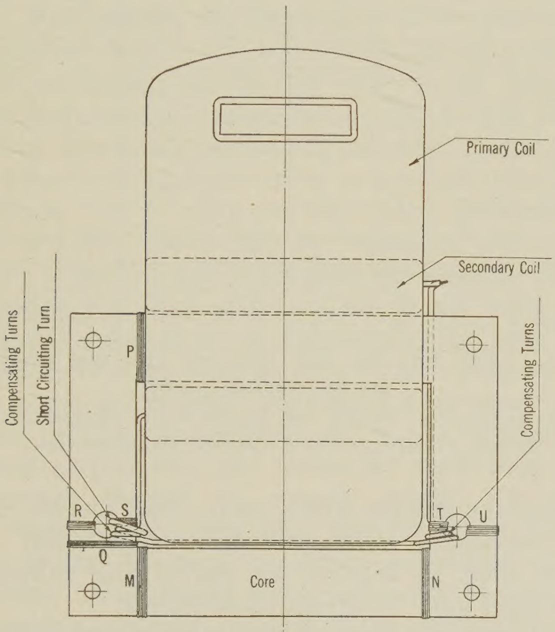

Fig. 4—15,000-Volt Compensated Current Transformer
(Letters indicate position of search coils used in making flux measurements.)

that it is merely necessary to have a portion of the primary flux change from section B to section A as the secondary current increases, in order that the secondary turns on the larger section may become more effective and increase the ratio of transformation. This change will occur when the flux density of section B is such that the reluctance increases more rapidly than the reluctance of section A. In order to produce this condition, it is necessary to operate section B on the descending side of the permeability curve so that as the secondary current increases, the reluctance of this section will increase at a faster rate than that of Section A operating lower down on the permeability curve. Due to the increase in secondary current or burden, the reluctance of the latter section may actually decrease as the flux density increases.

Although the ratio errors may be very materially reduced by the use of this type and construction of the magnetic circuit, it was considered impractical from a manufacturing standpoint for use in standard type of current transformers. Consequently, calculations, tests, and flux measurements were made on a transformer in which the parallel magnetic circuits were formed by an opening or hole through the laminations, as indicated in Fig. 4. The flux measurement proved that with the proper number of secondary turns on the parallel section of the magnetic circuit, it was possible to produce flux conditions in this region which had the same effect on the ratio characteristics as was obtained by the use of the permalloy shunt. This construction, satisfactory from both the electrical and mechanical standpoint, has been adopted by the General Electric Company in the manufacture of transformers using this method of compensation.

In Fig. 4 it will be noted that the secondary compensating turns enclose the narrow section of the magnetic circuit. The results obtained with the turns on either the narrow or wide section of the magnetic circuit are practically identical, providing the proper direction of winding is maintained. The direction of winding should be such that the instantaneous direction of the flux in the wider section of the parallel magnetic circuit, due to the current in these turns, will be opposite to the main flux. If these flux relations are maintained, as the flux density increases, a change in the main flux from sections, S or T to R or U, respectively, will produce practically identical results regardless of whether the compensating turns enclose the wide or narrow section of the parallel magnetic circuit.

The corrective idea described thus far concerns the reduction or elimination of the ratio errors of current transformers and has practically no effect on the phase angle. The phase angle for most current transformers, except those having a large number of ampere turns or having a large leakage reactance, are generally positive at lower current values and decrease as the current increases, until at full-load rating the phase angle may be zero, or even negative. Since a positive angle indicates that the secondary current reversed leads the primary current, it is evident that if the secondary current were lagged by the proper amount, the phase angle could be reduced to zero. Also, if this lagging effect diminished as the current is increased, under proper conditions it would be possible to correct for the large phase-angle errors at light loads or low currents and the small phase-angle errors occurring at full load.

The method used to reduce the phase-angle errors involves the use of a lag band which encloses the same section of the magnetic circuit as does the secondary corrective turns. The action of the current in this band causes the main flux to lag slightly, consequently lagging the secondary current and throwing it nearer in phase opposition to the primary current, and thus reducing the angle between the two currents. The action of this lag band may be likened to that of the lag band of a watt-hour meter, in which case the potential flux is caused to lag sufficiently to produce the quadrature relation between the flux and voltage of the potential element.

In the case of the compensated transformer the magnitude of the angles involved are so small that it is practically impossible to make flux measurements of sufficient accuracy to determine the exact manner in which the secondary current is caused to lag, also the reason for the change in the lagging effect as the flux density changes. Precision measurements of the phase angle accurately indicate the resulting effect of the lag band, and it is these results, of course, which are of primary importance.

Results

The curves in Fig. 7 indicate comparative results obtained on the high-grade metering type of transformer both with and without the new compensating feature. These results show the straight line ratio character-

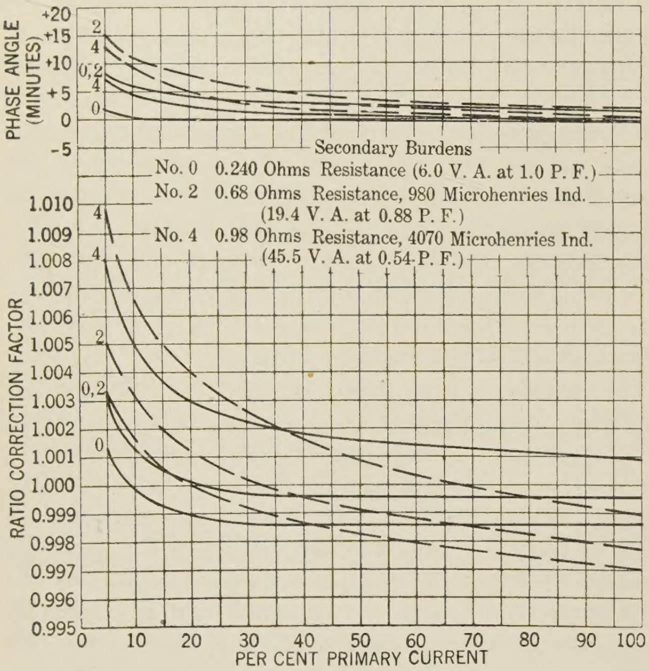

Fig. 7—Ratio and Phase-Angle Curves

60 cycles frequency
———— Compensated type, 15,000-volt current transformer
—— —— Same transformer without compensation

istics, obtainable with the new method of compensating current transformers. This is considered a valuable feature in view of the demand for long range metering equipments, since by the use of this method of compensation the transformer range has been considerably extended in the light load regions. Although the ratio errors for a secondary burden of 0.24-ohm resistance (6.0 volt-amperes at 1.0 power factor) are in the order of only 0.15 per cent, and for most high-grade metering considered negligible, a practically perfect over-all meter-transformer calibration may be obtained for values of secondary current from 10 per cent to 100 per cent load by merely adjusting the full-load calibration of the meter to take care of this error. For a secondary burden of 0.68-ohm resistance and 980-microhenry inductance (approximately 20 volt-amperes at 0.9 power factor) the ratio of transformation is practically perfect from 15 to 100 per cent load. From 5 to 15 per cent load the error is still small, approximately 0.25 per cent.

Variations in accuracy characteristics between transformers of the same type and rating are principally caused by variations in the quality of the steel used in the cores. While the compensating method does not directly reduce these errors, it does, by considerably

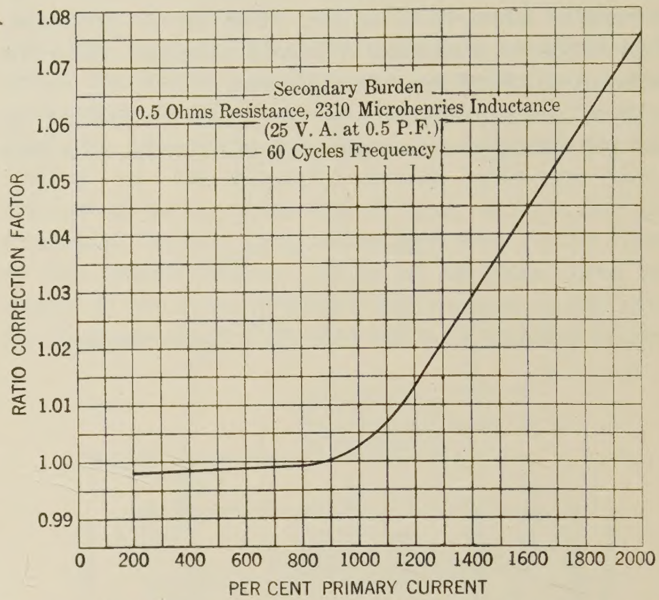

Fig. 8—Overload Curve on 15,000-Volt, 20-Ampere, 4:1 Ratio, Compensated Current Transformer

reducing the greater errors, make these smaller errors more important, which will result undoubtedly in a greater effort to improve the quality and uniformity of the steel used in current transformers.

Accuracy tests indicate that there is practically no difference in the effect of wave form on the characteristics of the transformer with or without the compensation.

The overload characteristics for this type of transformer are illustrated in Fig. 8. Tests indicate that there is practically no difference in the overload performance of the compensated and uncompensated transformers of the same type and rating.

The successful operation of protective methods employing differential and balanced relays largely depend on the similarity and uniformity of the current transformers characteristics under overload conditions. Since this compensating method can be applied to transformers of standard construction, both the compensated and uncompensated types can be used interchangeably for this service.

Accuracy tests indicate that there is practically no change in ratio or phase-angle characteristics for changes of 25 deg. cent. in ambient temperature.

The use of this new compensating feature in no way impairs the strength of the transformer to withstand over-current shocks.

The usual insulation value for breakdown between primary and secondary and primary to core can readily be maintained.

Abridgment of

Telemetering

BY C. H. LINDER[1] C. E. STEWART[1] H. B. REX[1] A. S. FITZ GERALD[1]
Associate, A. I. E. E. Associate, A. I. E. E. Non-member Member, A. I. E. E.

***Synopsis.**—In addition to surveying the field of application of "telemetering" and relating it to "supervisory control," the paper presents several innovations in the types of "telemeters" available. Operating requirements and channels available for the transmission of readings are discussed, and an installation of the varying frequency type of telemeter on the Montaup Electric Company's System is described.*

* * * * *

I. Introduction

AUTOMATIC performance has been applied extensively during the recent years to the generation, transmission, and distribution of electrical energy. Automatic devices and equipments are very satisfactorily performing duties that only a few years ago were performed by operators; so that a large number of men heretofore performing so-called minor duties have been released for more active and responsible positions. As a result, we find today stations under lock and key, visited only for inspection and maintenance, to provide for occurrences which require prompt operation of station equipment but do not occur in the ordinary automatic cycle, however, it has been found advisable to place these stations under the supervision of a power dispatcher. Automatic supervisory equipments provide the operator with visual indications of apparatus positions, and means for controlling power apparatus located at remote points. To obtain the most efficient operation, the dispatcher must be able to read electrical quantities at various outlying stations. A suggested way of doing this is to give the dispatcher television pictures of the substation instruments when a visual indication is required. While this method falls within the scope of modern engineering solution, at present it is not economically justified.

This paper deals with the telemetering problem of transmitting instrument readings or their equivalents from one point to another, which is one of transmitting approximate indications and records of quantities from remote points, and not one of transmitting quantities for metering and billing purposes.

II. Channels[2] Available for the Transmission of Readings

In the design of a telemetering equipment it is necessary to study the channel limitations and to design the terminal equipments accordingly. For economic reasons it is desirable to have as many readings as possible transmitted through a given channel. Among other factors, the optimum number of channels depends on the distance of a proposed transmission.

There are three important types of channels; multiconductor cables, wire construction, and transmission lines. The first two, cables and wire construction, are essentially metallic connections, although in some instances it is the practise to install insulating transformers to protect terminal equipments from high electrostatically or electromagnetically induced voltages. The third type of channel, the transmission line, requires the use of additional terminal equipment and coupling capacitors.

III. Terminal Equipments

Several successful types of terminal equipments are described below. The equipments were designed to satisfy the demands discussed in the previous sections of the paper.

A. Selsyn type. One of the simplest systems for remote indication consists essentially of two Selsyn motors. A Selsyn motor is an a-c. motor with a three-phase stator winding and a single-phase rotor winding. When two or more such motors have their stators connected together and their rotors excited from the same single-phase a-c. source, the rotors take the same relative angular positions. When one rotor is deflected, the rotors of all the other Selsyns are deflected by the same amount. Thus, one Selsyn operating mechanically from an instrument serves as a transmitter, and another Selsyn located perhaps miles away, taking the same position as the transmitter, serve as an indicator. Satisfactory remote indication may therefore be accomplished by having the receiving Selsyn actuate either the pointer of an indicating device or the pen of a recording device.

Selsyns are well adapted for use as remote indicators at relatively short distances. They are accurate and require little attention. However, the rotors of all the Selsyns in the system must be excited from the same source of alternating current, and three wires are required to connect the stators of the Selsyns.

It has been found that a transmitting Selsyn will actuate a remote indicator through lines that are equivalent to two miles of standard No. 19 B & S telephone cable. A remote recorder will operate satisfactorily over half of this distance. If an "in-

1. All of the General Electric Co.

2. The word "channel" as used in this paper refers to the path over which the readings are transmitted.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

dication transmitter" is used, the indication may be transmitted through an equivalent of from 12 to 30 mi. of cable, depending upon the type of receiver employed.

B. Rectified current type. When it is desired to transmit readings of a-c. amperes and a-c. volts, the very simple device shown in Fig. 1, consisting of only an instrument transformer, a rectifier, a transmission channel, and a milliammeter is available. Transmission by direct current instead of alternating current eliminates all trouble due to pilot-wire inductance and capacitance.

The rectifier transformer used in obtaining the voltage readings is a transformer operated from the secondary side of the main current transformer. The secondary winding is tapped at the middle; this is done in order to obtain full wave rectification of the power taken from the rectifier transformer.

The burden that each rectifier transformer imposes on the instrument transformer is approximately 10 volt-amperes; except that for the current transformer the burden is nearly doubled when the protective spark-gap operates. Thus, there is very little chance for overloading the instrument transformers with this equipment.

The full wave rectifier in the secondary of the rectifier transformer is of the hot-cathode type. The rectifier and metering circuit is as follows: The two terminals of the rectifier transformer secondary are connected to the anodes of the rectifier. The rectifier alternating current passes from the cathode of the rectifier through a pilot wire, a milliammeter at the receiving station, and another pilot wire, back to the midpoint of the secondary winding of the rectifier transformer.

The combined resistance of the line, receiver, compensating resistance, and the protective resistor of 2500 ohms, is 5000 ohms.

The receiver is a standard direct current indicating or recording instrument of the d'Arsonval type. It is calibrated in terms of the unit being measured.

C. The varying frequency impulse type. The three types of telemeter discussed above have depended primarily upon current or voltage magnitudes. Another type of telemeter is available which has a different principle of operation in that the readings are transmitted by means of impulses, the magnitude of the quantity being a function of the rate at which impulses are sent.

The transmitter used in this scheme is a meter of the same general type as the watthour meter. Since the operation of this system is according to the frequency of the impulses, the transmitter is commonly a rotating device which sets up these impulses by means of a contact making device—generally a small commutator. This commutator is geared to the motor shaft by a pair of gears of such a ratio that with full load (full scale reading) the meter originates approximately two impulses per second. Usually, this gear ratio is 1:1. The frictional load imposed by the commutator and brush is very small and is compensated for in the light load adjustment of the meter.

If the impulses from the watthour meter are used to actuate a speedometer, the speedometer mechanism may be calibrated so that its deflection indicates kilowatts. It is adapted to telemetering as follows: The impulses from the transmitter are received by a sensitive relay. This relay operates a portion of the telemeter known as the "rotary relay," whose function is to translate impulses into intermittent motion. By this means the output shaft of the rotary relay turns through one revolution for each impulse received.

This rotary relay consists of a motor controlled by an electrically operated latch that allows the motor to turn through one revolution each time the latch winding is energized by an incoming impulse. The shaft of the rotary relay is connected mechanically through a helical spring to a system of magnets comprising a flywheel. The flywheel possesses considerable inertia and the spring takes up the intermittent motion, so that the flywheel turns at a practically uniform speed proportional to the average frequency of the impulses received. The magnets induce eddy currents in a copper drum and thereby tend to produce rotation. The rotation of the drum is restricted by a spring, so that the deflection is proportional to the dragging force, and therefore to the speed of the magnets. The deflecting system has some inertia and is elastic, and consequently it must be damped to prevent mechanical oscillations.

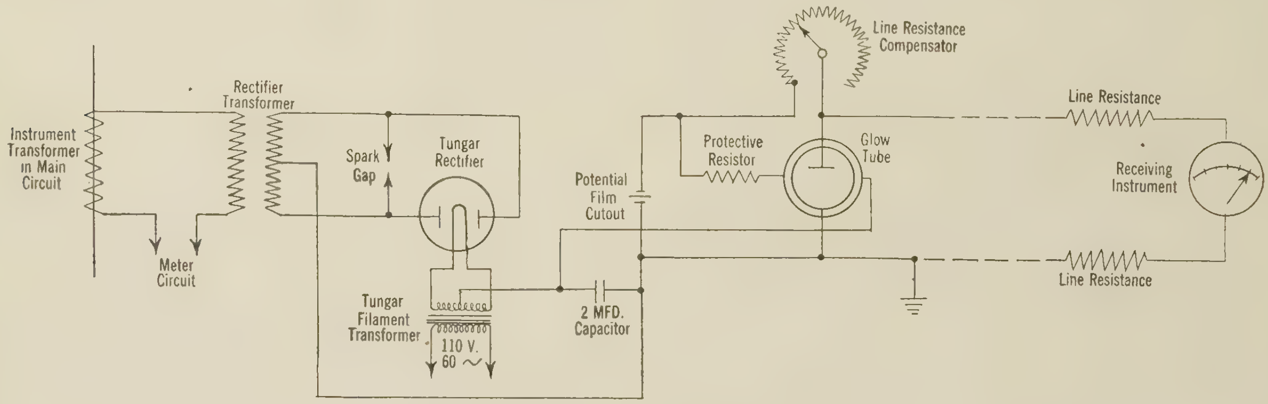

Fig. 1—Rectified Current Telemeter

The deflecting element actuates a pointer or pen to serve as an indicating or recording receiver. This instrument when operating on a frequency of two impulses per second has a torque of about 2000 gram-millimeters.

D. Vacuum tube type. Fig. 2 shows the apparatus which is employed. A small condenser is attached to the movement of the instrument whose reading is to be telemetered. This condenser is connected to an oscillator so that the frequency of the latter varies according to the meter position.

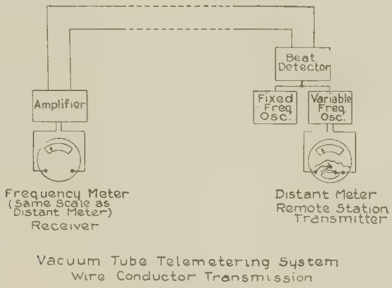

FIG. 2—VACUUM TUBE TELEMETERING SYSTEM WIRE CONDUCTOR TRANSMISSION

A second oscillator, operating at a frequency close to that of the first oscillator, has a fixed condenser, and therefore furnishes a constant frequency. A beat frequency is set up by these two oscillators and is detected by means of a third vacuum tube. This beat frequency is relatively low, and varies in accordance with the instrument deflection.

The beat or telemetering frequency is transmitted over the connecting line to the receiving station, where it operates a direct reading frequency meter. The frequency meter may be directly energized by the incoming signal or an amplifier may be provided, the method depending upon the nature of the line, its impedance, and on the energy level permissible.

The frequency meter is furnished with a scale which corresponds exactly to that of the distant instrument. It indicates at all times the position of the remote instrument. The receiving instrument indication depends upon frequency only, and, provided it receives more than the minimum power necessary to operate it, is not affected by changes in signal strength. Thus any changes in the impedance or leakage resistance of the line do not affect the accuracy.

If it is desired to transmit the instrument readings by carrier waves, over special conductors, telephone lines, or high voltage power lines, transmitting and receiving apparatus very similar to telephone communication equipment, which is already familiar in the Central Station field, is employed.

Fig. 3 is a schematic diagram of the general arrangement for carrier current telemetering. The heat frequency output of the oscillator circuit, instead of the output of a microphone speaking circuit, is applied in the regular way to the modulator. The carrier current generator consists of the usual arrangement of master oscillator and power amplifier. Thus there is sent out over the channel a carrier wave of constant frequency modulated by an audio frequency which varies with the magnitude of the quantity being telemetered.

At the receiving end, the carrier is demodulated and the audio signal amplified. The amplified signal is then taken direct to the frequency meter which reproduces the position of the pointer of the distant instrument. It will be specially noted that again the signal strength—provided it be sufficient to energize the apparatus—has no effect upon the accuracy of the indication.

The vacuum tube type is readily applicable to such special problems as: the totalizing of load indications at various points on a network, graphic recording,

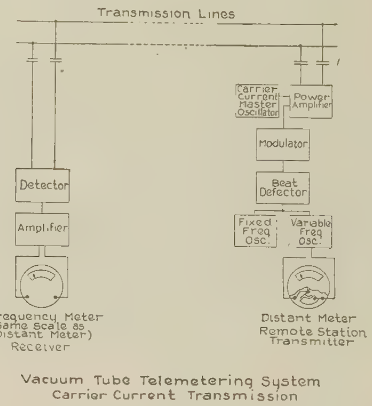

FIG. 3—VACUUM TUBE TELEMETERING SYSTEM CARRIER CURRENT TRANSMISSION

integrating, etc. Methods of carrying out these special applications involve some very interesting features which may be dealt with more appropriately on another occasion.

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The largest steam condenser in the world, to condense the steam from the world's largest single-unit turbo-generator, is now being assembled at the East River generating station of the New York Edison Company. As the bulk of the assembled unit would have been too large to ship by any means of transportation, the condenser was shipped in parts. The parts amounted to twenty carloads.

Nearly 700 tons of steam an hour will be condensed by this unit. There will be 90,000 square feet of cooling surface. Seven-eighth inch tubes will be used, whose total length would equal nearly 80 miles. To supply the cold water for the condensing, two 54-inch centrifugal pumps will draw 160,000 gallons of water from the East River every minute. This water is returned to the river as rapidly as used.

Abridgment of

Anomalous Conduction as a Cause of Dielectric Absorption*

BY J. B. WHITEHEAD† and R. H. MARVIN†

Fellow, A. I. E. E. Associate, A. I. E. E.

I. Introduction

THE two most important properties of an insulating material are high dielectric strength and long life. The close correlation with changes in dielectric loss clearly indicates that an understanding and control of the loss will point the way to longer life. The close relationship between dielectric absorption and dielectric loss has been shown experimentally,[37] and in fact the familiar decaying charging current curve under continuous voltage, typical of absorption, has been shown by Tank, Bouasse[37] and others to be sufficient to account for the essential characteristics of dielectric loss.

II. Purpose of the Work

It appeared desirable, therefore, to investigate more closely some of the more common dielectrics utilized in the manufacture of commercial insulation, with special reference to (1) a study of the charge and discharge absorption current curves at shorter intervals than heretofore observed, following the application and removal of voltage. This is the region of greatest influence on the value of dielectric loss. (2) To examine how closely these materials may be made by ordinary methods to approach the simple character postulated by Maxwell. (3) To study the dielectric properties of several substances, singly and in combination. (4) To study the mutual relationship of absorption and conduction as related to variations in temperature, electric gradient, and admixed impurities. As materials for study were selected some of the better known waxes and oils.

III. Apparatus and Methods

The several samples have been measured in a parallel plate condenser. The quantities measured are the charge and discharge current curves, the dielectric constant, the final conductivity, over a range of values of temperature and of electric gradient. For measuring the very small absorption current of good insulators, the Einthoven[7] string galvanometer was adopted.

An automatic switch operated by gravity was used for connecting the galvanometer into the condenser circuit, and in the case of discharge, the period of open circuit following charge was 0.005 sec.; the period of short circuit 0.0022 sec. The galvanometer was then cut in. Similar intervals obtained for the period of charge, these figures being obtained by oscillograms. An approximate computation indicated that the initial transient of the geometric charge was negligible before the galvanometer was cut in the circuit.

IV. Description of Materials

Paraffin. One of the best of the better known insulators. Ours was purchased as "Refined Wax;" melting point 128-130 deg. fahr. (53.4–54.5 deg. cent.). It was a hard white paraffin, the purest and most refined grade obtainable from one of the large manufacturers.

Other waxes studied were ceresine, spermaceti, carnauba wax and stearic acid.

Refined Lubricating Oil. A high-grade oil supplied by the Standard Oil Company of New Jersey, as their purest and highest grade insulating oil.

Black Oil. Furnished by request as a petroleum oil of poor insulating qualities for use in the study in mixtures. It is evidently in an intermediate stage of refining.

V. The Experiments

The chief observations were the charge and discharge absorption current curves as taken with the string galvanometer.

A large number of observations has been taken. Complete presentation is unnecessary. We give, therefore, in Figs. 2 to 5, a series of typical charge and discharge current curves as observed on various specimens. In all we have taken over 200 such curves. They constitute the principal record on which our conclusions are based. Three standard temperatures were used,—25, 35, and 45 deg. cent.,—and three standard voltages, 500, 1000, 1500 volts; nine sets of tests were made on each sample.

From the charging current records, the matter of chief interest is the excess of the current over the final conduction current, measured after one hour. The comparison of this excess of the current with the values of the discharge current indicates the possible presence of irreversible absorption current. In the tables are recorded the values of absorption current at 0.2, 0.4, and 0.8 sec., and also these values less the final conduction current denoted by i''.

From the records of discharge currents we have found

*Report to Engineering Foundation of an experimental research conducted in the Laboratory of Electrical Engineering of the Johns Hopkins University, Baltimore, Md.

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37. For numbered references see Bibliography, complete paper.

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it best to record the values taken at time intervals in geometric progression 0.1, 0.2, 0.4, 0.8, 1.6, 3.2 sec. The rate at which the current dies out is of significance and is indicated by the ratio of the current at 0.2 and 0.4 sec., and also at 0.4 and 0.8 sec.

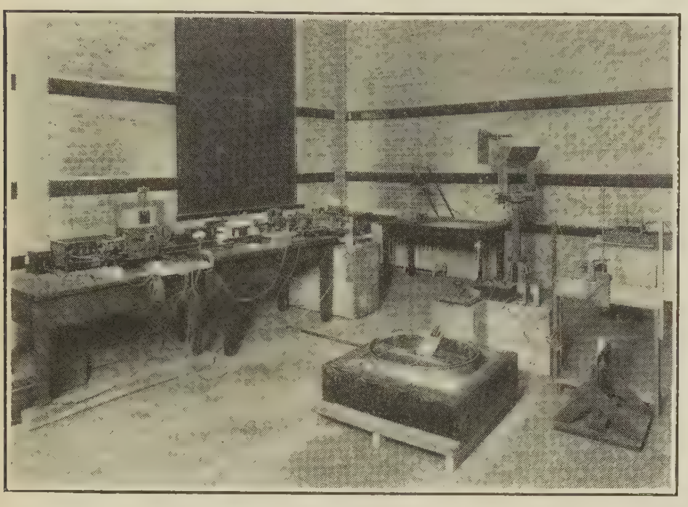

FIG. 1—GENERAL VIEW OF MEASURING EQUIPMENT

Left: String galvanometer and auxiliaries. Center: condenser, cover removed. Right: charge and discharge switch.

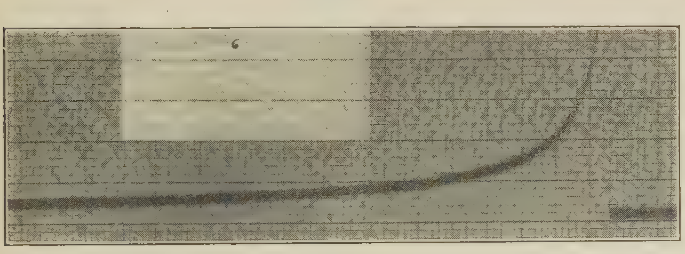

FIG. 2—SPECIMEN NO. 24—CARNAUBA WAX

Dec. 21, 1927—Charge—1500 volts
Temperature 46.1 deg. cent.
Sensitivity 6.28 $\times 10^{-8}$ ampere/mm.
Time, 1 small sq. = 1/25 sec.

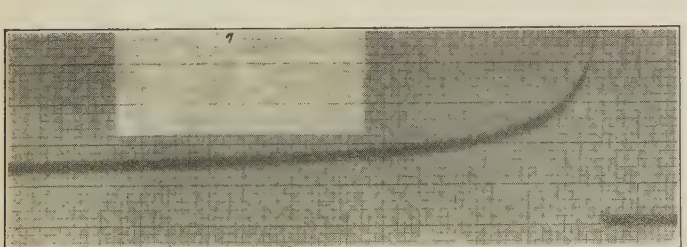

FIG. 3—SPECIMEN NO. 28—PARAFFIN, EQUAL PARTS GOOD AND BAD

Jan. 24, 1928—Charge—1500 volts
Temperature 45.2 deg. cent.
Sensitivity 6.24 $\times 10^{-8}$ ampere/mm.
Time, 1 small sq. = 1/25 sec.

VI. CHARACTERISTICS OF ABSORPTION CURVES

In Fig. 6 is shown a comparison between an actual curve and that given by the formula $i = I\,t^{-n}$, where I and n are constants. The constants have been so chosen that the curves intersect at 0.1 sec. and 2 sec. The agreement is seen to be fair. Such a curve is a straight line when plotted to logarithmic coordinates. A large number of our curves was so plotted and almost

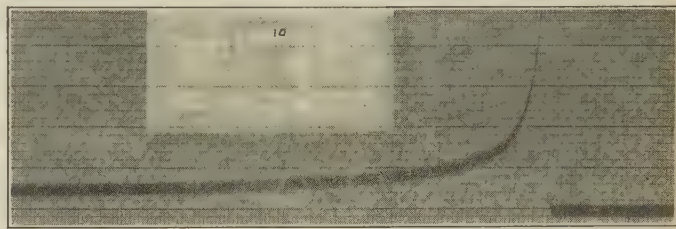

FIG. 4—SPECIMEN NO. 34—"BLACK OIL"

March 2, 1928—Discharge—1500 volts
Temperature 45 deg. cent.
Sensitivity 3.92 $\times 10^{-9}$ ampere/mm.
Time, 1 small sq. = 1/25 sec.

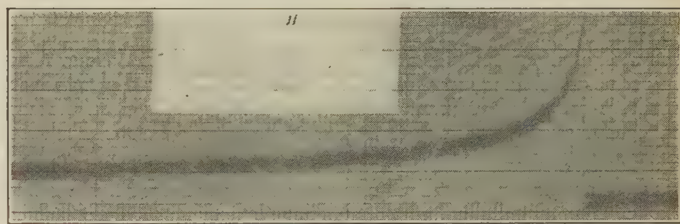

FIG. 5—SPECIMEN NO. 38—PARAFFIN 99 PER CENT, "BLACK OIL" 1 PER CENT

March 28, 1928—Discharge—500 volts
Temperature 25.1 deg. cent.
Sensitivity 2.09 $\times 10^{-9}$ ampere/mm.
Time, 1 small sq. = 1/25 sec.

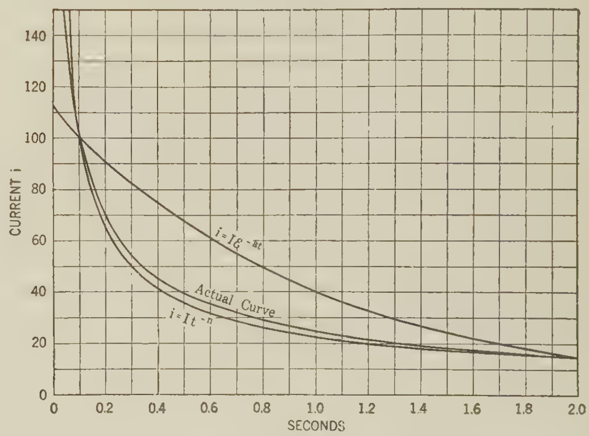

FIG. 6—COMPARISON BETWEEN ACTUAL ABSORPTION CURVE ON DISCHARGE AND EMPIRICAL EXPRESSIONS

Actual curve, paraffin, specimen No. 28, at 45.3 deg. cent. and 1500 volts, Plotted to arbitrary scale of 100 at 0.1 sec.
Empirical curves drawn to intersect actual at 0.1 and 2 sec.

invariably gave a line slightly concave towards the time axis.

The negative exponential $i = I\,E^{-at}$ has also been plotted on Fig. 6, in the same manner. Its simplicity and definite value at zero time make it attractive, but

the deviation from the actual curve is so great that it is scarcely even a rough approximation. This curve has particular interest from the fact that it is that indicated by Maxwell's analysis. This departure of the results of experiment from the indication of this simple theory has often been noted and is one reason for the discredit now commonly attached to the validity of Maxwell's proposal.

XII. Results and Discussion

The main conclusions of the work are as follows:

1. The shape of the current-time curve of the absorption current on discharge is essentially the same with every substance studied. Its striking peculiarity is a very rapid decrease at first, followed by a very gradual dying out. No simple mathematical formula has been found to express this relation satisfactorily. There is a fair approximation to the relation $i = A\,t^{-n}$. The variation from the negative exponential relation, as proposed by Maxwell, is very wide.

2. All the solid dielectrics showed appreciable absorption. Heating at reduced air pressure in no case reduced the absorption. The absorption was approximately proportional to the final conduction in all cases. There was no indication that the simple dielectric having conductivity but no absorption, as postulated by Maxwell, can exist.

3. Noticeable departures were found from Curie's law of proportionality between the ordinates of the current time curve on discharge and the charging voltage.

4. The absorption current on discharge falls off more rapidly the higher the charging voltage.

5. The conduction in general increases with the voltage. In a few cases there is evidence of the approach to a saturation current.

6. In general both conduction and absorption currents in solids increase with rise in temperature. As the melting point is approached the absorption current falls off, and usually almost disappears on complete fusion, as noted by other observers.

7. In some instances a decrease was found in both conduction and absorption as the temperature rose. While an exception to 6 they agree with it in showing a proportionate change in both conduction and absorption currents.

8. Reversible absorption in liquids, while not as conspicuous as in solids, is very noticeable in some cases. This shows that whatever the nature of absorption it is not fundamentally related to the solid state.

9. Any treatment of a dielectric, such as prolonged heating, which increases or diminishes the conduction, increases or diminishes the absorption current in much the same proportion.

10. There is evidence that a mixture of two solid dielectrics acts much the same as though the two were separate.

11. The addition to a solid dielectric of a conducting liquid which can mix with it causes a large increase in the absorption. The absorption current is much greater, and falls off far more slowly than can be explained by Maxwell's theory.

12. The solids tested gave no definite evidence of irreversible absorption current. However, mixtures of paraffin with a small percentage of conducting oil, showed at 45 deg. cent. a noticeable irreversible absorption current.

The most striking feature throughout these studies is the intimate connection between the absorption and the conduction. Increase or decrease in either, under the influence of other variables, is accompanied always by a similar change in the other. Other observers have noted a similar correlation. We have shown that it extends over such a wide range of materials and conditions as to make it certain that the ultimate seat of the phenomenon of absorption is to be found in the laws of ionic conduction.

The anomalous conduction found in dielectrics both liquid and solid offers a far more promising prospect for the explanation of dielectric absorption. We use the word "anomalous" since conduction in dielectrics rarely follows Ohm's law. If electrons are involved in this conduction, their contribution is in general overshadowed by that of much larger, heavier, and slower ions. This is true for both liquids and solids. All the work of recent years points to this type of conductivity. It may be seen at once how readily the conception lends itself to an explanation of absorption. The ions being large and slow, move towards the opposite electrodes; in doing so they upset the potential gradient; or, if by any cause their motion is interrupted, they may accumulate and by the resulting space charge cause the counter or polarization e. m. fs. often reported. There are, however, obvious difficulties in this simple picture, some of which we discuss below.

Curie[3] describes experiments on porous porcelain showing pronounced absorption, which decreased as the porcelain was dried. From this he suggests polarization as the cause of absorption, but makes no attempt to develop a complete theory.

Joffe[11] has extensively investigated the absorption in crystals, and considers it due to the motion of both ions and electrons, resulting in a polarization in the crystal. He finds two distinct types of polarization; one represented by Iceland spar, the other by quartz. With Iceland spar, if the crystal is charged, and a thin layer, as little as 0.01 mm., removed from the side next to the cathode, the residual charge disappears. If the layer is removed from the side adjoining the anode, no change is noticed. With quartz the removal of layers from either side has only a small effect. The potential changes gradually and symmetrically through the crystal.

The fundamental difficulty in a proposal of polarization, due to space charge, as an explanation of dielectric absorption is the inconsistency of the idea of a free flow

of charge through the mass of the dielectric, this charge being more or less abruptly halted at the surface of the dielectric, where the latter is in contact with a metallic electrode. There is ample evidence of the motion of the ions, even in a solid dielectric. It is important to note, however, that Joffe reports only one case of a sharply defined surface layer of charge, with consequent high potential gradient to the electrode, and that even in so good an insulator as quartz, it was apparent that the internal accumulation of charge was spread over a much greater volume and the variation of potential gradient, although not uniform, was gradual rather than abrupt.

We have already called attention to the variation of density of distribution of the ions in a conducting insulating liquid, when subject to electric stress. In many cases this results in a marked variation in potential gradient near the electrodes, as long ago shown by Mie,[41] Warburg,[35] and others. This leads to the question of the influence of this accumulated space charge on the external field as a possible explanation of the typical current-time curves, often noticed in viscous liquids and similar to those observed in solids. We have reported above one especially conspicuous case. The difficulty here, as in the case of polarization in solids, is to explain the failure of this accumulated charge to pass to the electrodes. We venture to suggest that this difficulty in the case of the liquids may be explained by assuming that an ion, owing to its intense electric field, surrounds itself with an atmosphere of neutral molecules which move with it, and which when an obstacle, such as an electrode, is encountered, prevents the charge ion from passing to it. Extending this conception we can easily conceive the accumulation of layers of space charge in the proximity of the electrodes. Simple mathematical analysis of the influence of this space charge on the applied electric field of a parallel plate condenser, leads to the negative exponential current-time relation approximating the charging current time curves, as often observed in experiment.

The increasing evidence that absorption and conduction always go hand in hand, and that the latter in solids frequently partakes of the character of that of gaseous and liquid ions, emphasizes clearly that further progress towards a better understanding of the phenomena in dielectrics can best be obtained through a study of this type of ion. Moreover, as it is the slow moving ions which are of the greatest interest and importance, we propose, as a continuation of this work, further studies of ionic mobilities and conductivities as found in liquid insulators of increasing viscosity, merging into the type of solid compounds such as studied in this paper and those commonly used for electrical insulation.

The work has been carried out under the provisions of a grant by the Engineering Foundation to the Johns Hopkins University, the problem being sponsored by the American Institute of Electrical Engineers. Contributions to the fund have been made by a number of industrial corporations. The authors wish to express their appreciation of the constant interest and encouragement of the Engineering Foundation and of the support of the contributing companies. Thanks are also due to Dr. W. B. Kouwenhoven and to other members of the technical staff of the School of Engineering, The Johns Hopkins University, for many instances of cooperation and assistance.

A RULE FOR D-C. MACHINE RELATIONSHIPS

The following method of stating some fundamental relations of the direct-current dynamo is a great time saver when analyzing a changed condition of operation.

A given machine may operate:

1—As generator or motors.
2—With a certain direction of rotation.
3—With a certain direction of armature current.
4—With a certain polarity of main field.

The rule to be followed is that these four operating conditions must be changed in pairs. That is, any two or all four can be changed, but no single condition can be altered.

For example, suppose a direct-current shunt generator is being used as a load for a mechanical source of power and is feeding current into a constant voltage system. If the driving power fails, the machine will become a motor and will continue to run from the line in the same direction as a motor. In this case, items 1 and 3 change.

A compound generator has its series field winding permanently connected to the armature. The shunt field is separately excited. Can this machine be operated in the same direction of rotation as a motor without becoming unstable in speed due to the series and shunt fields opposing each other? Item 1 is to be changed and item 2 is not to be changed, therefore, either 3 or 4 but not both can be changed. If the direction of armature current is changed, the series field also reverses and therefore opposes the shunt field. The operation would therefore be unstable.

It is well known that a direct-current series traction motor must have its field connection reversed in order to build up as a series generator for dynamic braking. In this case item 1 is to be changed and item 2 not changed. Therefore, either 3 or 4 but not both can be changed. In the case of a series generator, the ability to build up its voltage depends on the armature current passing through the field in such a direction as to aid the residual field. The reason for changing the field connections is to be able to change the direction of armature current, item 3, without changing the field polarity, item 4.

Many other questions of this nature may readily be answered by this rule rather than attempting to analyze the result by the absolute directions of current, fluxes, and rotation in the given machine.—*C. A. Atwell in the Electric Journal.*

Abridgment of

The Revolving Field Theory of the Capacitor Motor

BY WAYNE J. MORRILL*

Associate, A. I. E. E.

***Synopsis.**—The paper presents an accurate theory of the split-phase motor, both as regards starting and running performance. The general equations for an unbalanced two-phase motor are first derived, and the results are then applied to the special case of the capacitor motor. Evidence of the validity of the theory is given in the form of curves, comparing test results with calculations.*

The principal factors affecting practical capacitor motor design are discussed, and finally the performance characteristics of the motor are compared with those of repulsion-start induction motors. It is concluded that the capacitor motor has important advantages which will justify its extensive use.

The complete derivation of the theory is given in an appendix.

INTRODUCTION

WITH the rapid increase which has recently taken place in the number of motors applied to such semi-continuously-operated domestic loads as household refrigerators and oil burners, there has arisen a demand for fractional horsepower motors of very high quality. Such motors operating on house lighting circuits as they do, and running at all times of the day and night, must be quiet, have high operating characteristics, low starting current to prevent flicker of lights, and no radio interference. Of all the types of single-phase fractional horsepower motors available, the capacitor motor seems best suited for this sort of service. It has not only all of the necessary characteristics, but is in addition probably the simplest and most reliable of all high quality single-phase motors.

The purpose of this paper is to present the revolving field theory of the capacitor motor, and to show how, by the use of this theory, it is possible to explain and calculate the phenomena which appear in the operation of the motor. In addition to presenting the theory, an effort will be made to show that the possession of a sound theory is of great assistance in the design of a line of motors.

Of interest are the single-phase motor equations which can be obtained as the special case of a capacitor motor in which the auxiliary phase carries no current. It is believed that this method of treatment of a single-phase induction motor represents an advance in the art. By means of this treatment, the complete torque equation including the alternating single-phase torque is obtained.

A capacitor motor is really an unbalanced two-phase motor, in which both of the stator phases are connected directly across the same line. For this reason, the equivalent circuit and general equations for an unbalanced two-phase motor will be first obtained, and after a brief discussion of the possible capacitor motor connections, these equations will be applied to the calculation of capacitor motor performance.

THE GENERAL EQUATIONS OF AN UNBALANCED TWO-PHASE MOTOR

So far as the writer is aware, the general equations for the unbalanced two-phase motor were first derived by Mr. P. L. Alger, early in 1924, as an extension of the A. I. E. E. article[1] he published at that time. The derivation of the general theory given here is largely founded on that work. In carrying on the further studies described in this paper, the writer has received encouragement and many helpful suggestions from Messrs. A. F. Welch, A. R. Stevenson, Jr., P. L. Alger, and C. J. Koch, to whom he wishes to express his obligation.

The equivalent circuit for a single-phase motor having a primary impedance of $R_{1M} + j\,X_{1M}$ and the primary winding of which is called the M phase is represented in Fig. 1A.

If instead of the M phase there is an S phase displaced backward in position by 90 deg., electrical, from the position of the M phase and having a times as many turns as the M phase, the single-phase equivalent circuit for the S phase is shown in Fig. 1B. In the S equivalent circuit the primary impedance is $a^2 R_{1S} + j\,a^2 X_{1S}$ and the external series impedance is $R_c + j\,X_c$.

If both the M and the S phases exist on the motor and are excited simultaneously, their fluxes superimpose without distortion and the equivalent circuits are the same as before except that in addition to the forward and backward voltages self induced in each phase there is a forward and backward voltage due to the fluxes of the other phase. Under this condition, the equivalent circuit becomes as shown in Fig. 2 wherein the divided circuits have been replaced by series impedances of equal value.

Since the M phase is displaced forward by 90 electrical degrees from the S phase, the voltage generated

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1. See Bibliography.

in the M phase by the S forward flux must lag by 90 time degrees the voltage which the same flux produces in the S phase and since the turns on the M phase are to those on the S phase as 1 is to a, the magnitude of the M voltage must be $\frac{1}{a}$ times that of the S phase.

From these considerations the equation for the im-

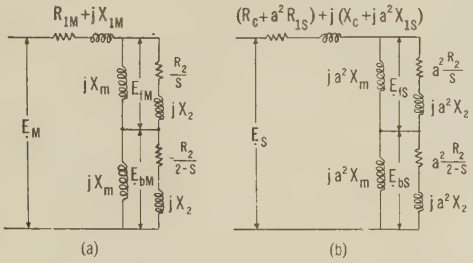

Fig. 1—Single-Phase Motor Equivalent Circuits

pressed voltage equivalent to the voltage produced in the M phase by the S forward flux is:

$$\bar{E}_{\underset{Sf}{M}} = -j \frac{1}{a} \bar{E}_{fS} \tag{1}$$

By a similar line of reasoning the impressed voltages

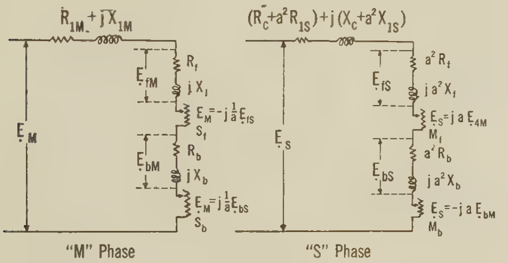

Fig. 2—Unbalanced Two-Phase Motor Equivalent Circuit

equivalent to the other mutually generated voltages can be shown to be the values given on the equivalent circuit.

The equations for the voltages impressed on each of the primary phases are, from Fig. 2:

$$\bar{E}_M = \bar{I}_M [(R_{1M} + R_f + R_b) + j (X_{1M} + X_f + X_b)] - j \bar{I}_S a [(R_f - R_b) + j (X_f - X_b)] \tag{2}$$

$$\bar{E}_S = \bar{I}_S [R_c + a^2 (R_{1S} + R_f + R_b) + j X_c + j a^2 (X_{1S} + X_f + X_b)] + j \bar{I}_M a [(R_f - R_b) + j (X_f - X_b)] \tag{3}$$

Current Equation for an Unbalanced Two-Phase Motor

The simultaneous solution of (2) and (3) gives for the currents of an unbalanced two-phase motor:

Equation for Average Torque of an Unbalanced Two-Phase Motor

If the current in the M phase be:

$$\bar{I}_M = A + j B \tag{6}$$

and that in the S phase be:

$$\bar{I}_S = \mathbf{g} + j \mathbf{h} \tag{7}$$

the equation for the average torque can be shown to be:

$$T_{avg} = [I_M^2 + a^2 I_S^2][R_f - R_b] + 2 a [A \mathbf{h} - B \mathbf{g}][R_f + R_b] \tag{8}$$

Since:

$$A \mathbf{h} - B \mathbf{g} = I_M I_S \sin \phi \tag{9}$$

Equation (**8**) may be reduced to (**110**) of Appendix I.

In addition to the average torque of Equation (**8**) there is an alternating torque produced through the action of the forward flux and backward current and vice versa.

Equation for Alternating Torque of an Unbalanced Two-Phase Motor

In Appendix I, Equation (**111**), it is shown that the maximum value of the alternating torque is:

$$T_{\underset{Max}{\sim}} = \sqrt{[I_M^4 + a^4 I_S^4 + 2 I_M^2 I_S^2 a^2 \cos 2\phi][(R_f - R_b)^2 + (X_f - X_b)^2]} \tag{10}$$

It will be noticed that the alternating torque ceases

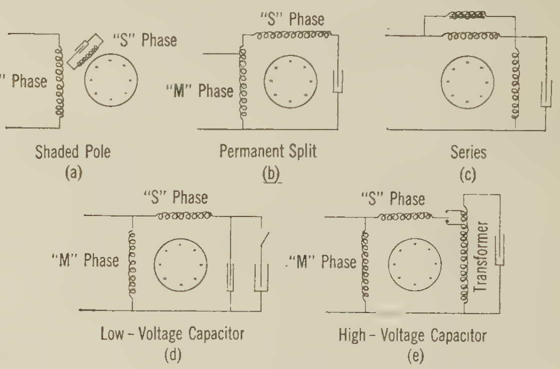

Fig. 3—Capacitor Motor Diagrams

to exist when $I_S\, a$ is equal to I_M and ϕ is 90 deg.

The Capacitor Motor

A capacitor motor can be built in a number of forms as shown in Fig. 3.

The equations for each of the possible forms of a capacitor motor have been derived but careful investigations have shown that except in special cases the

$$\bar{I}_M = \frac{\bar{E}_M \{[R_c + a^2 (R_{1S} + R_f + R_b)] + j [X_c + a^2 (X_{1S} + X_f + X_b)]\} + j \bar{E}_S a [(R_f - R_b) + j (X_f - X_b)]}{\{[R_c + a^2\, {}_S R_{1S} + R_f + R_b)] + j [X_c + a^2 (X_{1S} + X_f + X_b)]\} \times \{[R_{1M} + R_f + R_b] + j [X_{1M} + X_f + X_b]\} - a^2 [(R_f - R_b) + j (X_f - X_b)]^2} \tag{4}$$

$$\bar{I}_S = \frac{\bar{E}_S [(R_{1M} + R_f + R_b) + j (X_{1M} + X_f + X_b)] - j \bar{E}_M a (R_f - R_b) + j (X_f - X_b)]}{\{[R_c + a^2 (R_{1S} + R_f + R_b)] + j [X_c + a^2 (X_{1S} + X_f + X_b)]\} \times \{[R_{1M} + R_f + R_b] + j [X_{1M} + X_f + X_b]\} - a^2 [(R_f - R_b) + j (X_f - X_b)]^2} \tag{5}$$

two forms in d and e of Fig. 3 are the most desirable from considerations of simplicity and economy.

There is no difference between the motor shown in Fig. 3d and that shown in Fig. 3e except in the method of applying the capacitor. It has been found possible to impress a much higher voltage upon a capacitor for the short time required to start a motor than could be impressed continuously. Advantage has been taken of this fact in Fig. 3e by the use of an auto transformer

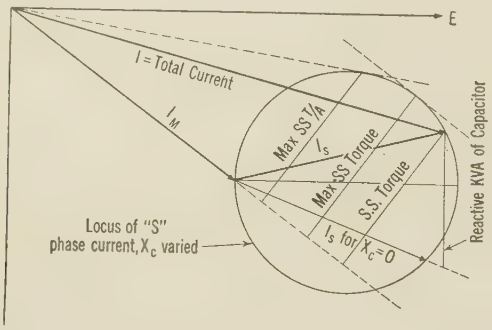

Fig. 4—Capacitor Motor Starting Diagram

which raises the voltage on the capacitor during the starting period and then by a change in taps reduces the voltage to a value safe for continuous operation. In addition to the change in voltage, the transformer makes it possible to impress upon the capacitor the exact voltage which is desired, regardless of the motor design.

The Capacitor Motor Current and Torque Equations

For purposes of analysis it is possible to represent either the capacitor of Fig. 3d or the capacitor transformer unit of Fig. 3e by a resistance in series with a condensive reactance. If these values be substituted for the external impedance $R_c + j\,X_c$ in the unbalanced two-phase equations and the voltage $\bar{E}_M$ be substituted for $\bar{E}_S$ the unbalanced two-phase equations apply directly to a capacitor motor.

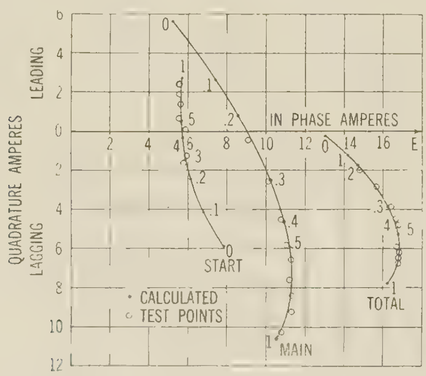

Fig. 5—Vector Current Relations for Starting Condition of a ¼-Hp. Capacitor Motor

Slip varied from "1" to "0"
. Calculated ⊙ Test points

CONSTANTS

R_{1M}	= 2.02	X_{1M}	= 2.79	X_M	= 33.4
R_2	= 2.06	X_2	= 1.06	a	= 1.18
R_{1S}	= 5.12	X_{1S}	= 2.31	Wf	= 13
Rc	= 3	Xc	= − 14.5	Wi	= 24

The unbalanced two-phase torque equations are not affected by the above substitutions and apply without change to a capacitor motor.

Capacitor Motor Output

As shown in Equation (112) the equation for net output is:

$$W.\,O. = \{\,[I_M^2 + a^2\,I_S^2]\,[R_f - R_b] + 2\,I_M\,I_S\,a\,[R_f + R_b]\sin\phi\,\}\,(1 - s) - W_f \qquad (11)$$

wherein W_f is the watts friction loss.

Total or Line Current of a Capacitor Motor

The total current $\bar{I}$ of a capacitor motor is equal to the sum of $\bar{I}_M$ and $\bar{I}_S$ and if it be represented as follows:

$$\bar{I} = C + j\,F \qquad (12)$$

the equation for the input may be written:

$$W.\,I. = C\,E_M + W_i \qquad (13)$$

in which W_i is the iron loss.

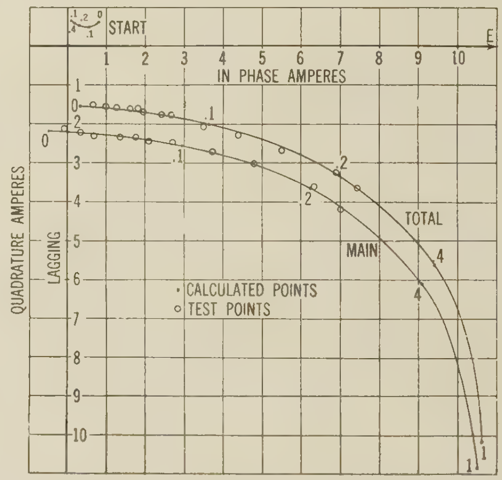

Fig. 6—Vector Current Relations for Running Condition of a ¼-Hp. Capacitor Motor

Slip varied from "1" to "0"
. Calculated ⊙ Test points
Constants are the same as Fig. 5 except Rc = 9 and Xc = − 172

Starting Diagram for Capacitor Motors

Equations (14) and (17) are useful but a starting diagram has been devised which furnishes graphically the same information as that given by the current and torque equations, and at the same time gives a complete picture of all the quantities involved in the starting of a capacitor motor. This diagram is so simple and convenient to use that it is desirable to present it at this time.

If the locus of the total current $\bar{I}$ as X_c is varied be plotted, the result is the circle shown in Fig. 4. From this circle the various starting quantities can be read in the manner indicated on the diagram.

It will be noticed that the maximum torque per ampere occurs when the total current is tangent to the circle and the maximum torque occurs at the point where a line parallel to $\bar{I}_M$ is tangent to the circle.

Capacitor Motor Characteristics

The calculated current loci for a capacitor motor as its speed is varied are shown in Figs. 5 and 6. Loci for both the starting and running connections are given and the torque and performance corresponding are given in Fig. 7.

On the preceding figures the circled points are test results. It will be noted that the calculations check the tests remarkably well.

On both "current loci" and "speed torque" curves the unstable nature of the S phase current will be noticed. At high speeds, the capacitor current and voltage increase rapidly making it desirable to change connections in order to secure economy and good operating characteristics.

Not only is the magnitude of the S phase current

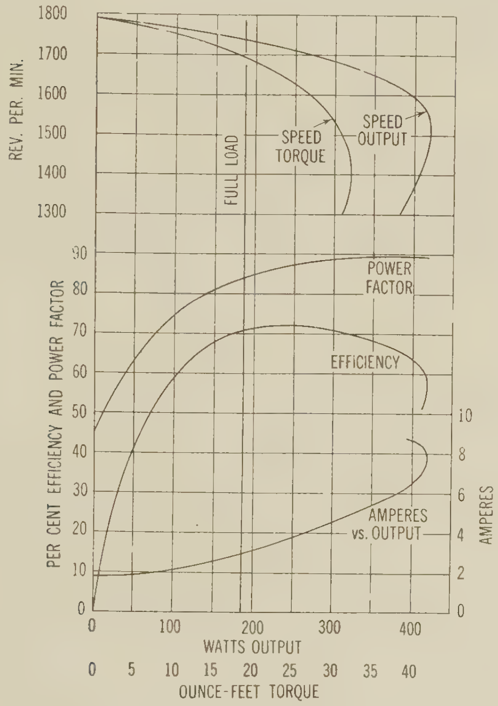

Fig. 7—Performance Characteristics of ¼-Hp. Capacitor Motor

(Same constants as Fig. 6)

unstable but its angular displacement also varies and with the starting connection the vectors actually cross over so that the second component of torque in Equation (**8**) becomes reversed in sign and acts to reduce the torque.

For purposes of comparison Fig. 8 is inserted to show the calculated performance of the same motor with the S phase disconnected and operated as a single-phase induction motor.

Double Frequency Torque

The alternating torque of a capacitor motor is given by Equation (**10**). While it is possible to approach the condition of zero alternating torque over a given range of load by properly proportioning the S phase and the capacitor, this condition is seldom actually obtained. With a capacitor correctly specified for running operation, the alternating torque is always reduced, generally to less than half that of an equivalent single-phase motor. (See Fig. 12).

As an illustration of the sort of results obtained in practical design Fig. 11 is presented showing a comparison of a ¼-hp. capacitor motor now in regular production with a composite repulsion start induction curve

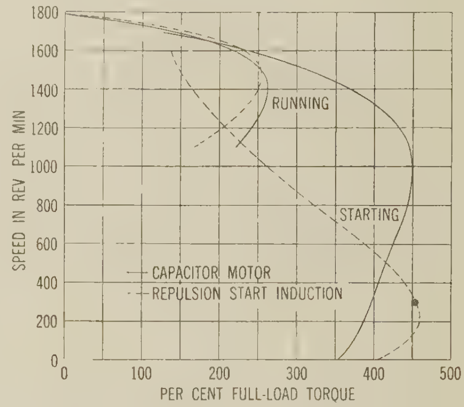

Fig. 11—Torque Curves of ¼-Hp. Capacitor Motor

vs.

¼-hp. repulsion start induction motor
(Average of several makes)
———— Capacitor motor
- - - - Repulsion start induction

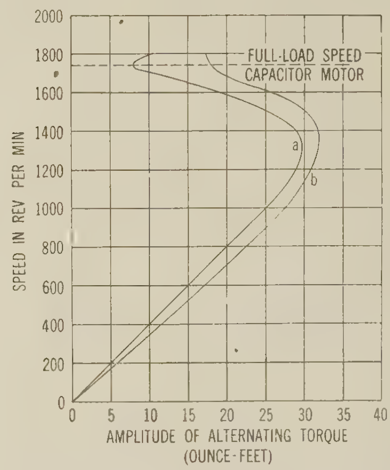

Fig. 12—Amplitude of Alternating Torque *vs.* Speed

(Same constants as Figs. 6 and 8)
(a) ¼-hp. capacitor motor
(b) Same motor operated single phase

obtained by averaging the values for several of the leading makes of repulsion start induction motors.

It will be noted that the pull-up torque of the repulsion start induction motor is less than the maximum running torque whereas the capacitor motor will pull up all it can carry.

Conclusions

The foregoing theory and discussion of the capacitor motor have shown its possibilities as a very high quality motor. It has the following points of merit: (a) It has excellent torque characteristics, being

able to start and accelerate all it can carry; (b) its starting current is low, being only about 30 per cent to 50 per cent greater than that of a repulsion start induction motor of equal rating or about ½ that of a split phase motor of less torque; (c) its power factor is high, due to the use of the capacitor for power-factor correction after it has completed its duty in starting the motor; (d) the motor noise is reduced, due to the reduction in double frequency torque and due to the fact that there are no brushes or other rubbing contacts; (e) the motor is free from radio interference because it has no brushes.

Acknowledgment

The writer wishes to acknowledge his aprreciation of the valuable assistance rendered by his associates in making calculations and plotting curves for this paper.

Nomenclature

A = "In phase" component of M phase current

a = Ratio $\dfrac{\text{Fundamental conductors on } S \text{ phase}}{\text{Fundamental conductors on } M \text{ phase}}$

$a^2 R_{1S}$ = Primary resistance of S phase

$a^2 X_{1S}$ = Primary leakage reactance of S phase

B = "Reactive" component of M phase current

C = "In phase" component of total current

$\bar{E}_M$ = Vector voltage impressed on primary of M phase

$\bar{E}_S$ = Vector voltage impressed on primary of S phase

F = "Reactive" component of total current

$\mathbf{h}$ = "Reactive" component of S phase current

$\bar{I}$ = Vector total current

I = Effective value of total current

$\bar{I}_M$ = Vector M phase current

I_M = Effective value of M phase current

$\bar{I}_S$ = Vector S phase current

I_S = Effective value of S phase current

$\mathbf{g}$ = In-phase component of S phase current

R_{1M} = Primary resistance of M phase

R_2 = Secondary resistance reduced to M phase

R_c = External resistance in series with S phase

R_b = Apparent resistance to M phase backward field

R_f = Apparent resistance to M phase forward field

T_{avg} = Average value of developed torque

T_{SS} = Standstill torque

$T_{\sim max}$ = Maximum value of alternating torque

W_f = Watts friction and windage loss

W_i = Watts fundamental iron loss

$W.I.$ = Total watts input

$W.O.$ = Net watts output

X_{1M} = Primary leakage reactance of M phase

X_2 = Secondary leakage reactance reduced to M phase

X_c = External reactance in series with S phase

X_b = Apparent reactance to M phase backward field

X_f = Apparent reactance to M phase forward field

X_m = Magnetizing reactance of M phase

ϕ = Angle by which $\bar{I}_S$ leads $\bar{I}_M$

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Abridgment of
TWO-REACTION THEORY OF SYNCHRONOUS MACHINES
Generalized Method of Analysis—Part I

By R. H. Park*

Associate, A. I. E. E.

Starting with the basic assumption of no saturation or hysteresis, and with distribution of armature phase m. m. f. effectively sinusoidal so far as regards phenomena dependent upon rotor position, general formulas are developed for current, voltage, power, and torque under steady and transient load conditions. Special detailed formulas are also developed which permit the determination of current and torque on three-phase short circuit during starting, and when only small deviations from an average operating angle are involved.

In addition, new and more accurate equivalent circuits are developed for synchronous and asynchronous machines operating in parallel, and the domain of validity of such circuits is established.

Throughout, the treatment has been generalized to include salient poles and an arbitrary number of rotor circuits. Thus the analysis is adapted to machines equipped with field pole collars, or with amortisseur windings of any arbitrary construction. Previous theories have not recognized these circuits.

It is proposed to continue the analysis in a subsequent paper.

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

29-33

Abridgment of

Electrical Aids to Navigation*

BY ROBERT H. MARRIOTT†

Fellow, A. I. E. E.

Synopsis.—Electrical and magnetic aids to navigation by water and air are outlined in this paper. The principal subjects discussed are the earth inductor compass, the radio compass, the radio beacon, submarine signals, depth finders, distance finders, channel-marking signals, fog-penetrating lights, height indicators for aircraft, etc. A bibliography is included in the complete paper.

THIS paper points out that there are numerous ways in which electricity and magnetism aid air and water navigation, partially describes and illustrates some of the less familiar aids which are in use or are coming into use, and mentions some aids that may come into use.

Magnetism as an aid to navigation goes back to the more romantic probabilities, history, and tradition of the past. By tradition, natural magnetic iron is said to have been known as far back as 2634 B. C.

The word "navigation," judging from the Latin words from which it is derived, originally related to the moving or propelling of a ship; now we usually consider the word in connection with the steering of a ship. Electricity, however, aids under both meanings. Battleships are driven by a-c. motors and submarines are driven from storage battery power by d-c. motors; electric winches are used to pull vessels into dock; electrically-driven gyroscopes are used to make ice-breaking ships roll and to keep yachts from rolling; electric ignition is used in the propulsion of both air and marine craft.

Almost every form of electrical communication, signaling, and remote-control device is used as an aid to navigation.

The gyro-compass is a gyroscope, but it depends upon electricity for its motive power and for the operation of the control devices which go with it.

Practically all of the electrical comforts used on land contribute to the comforts in the navigation of the modern steamships.

The coming of air navigation is expanding the use of electrical devices for aiding that rapidly growing navigation. The success of air navigation apparently depends largely upon the ability of aircraft to dodge dangerous storms. To do this, the aircraft must be fast and the pilots must know where storms are, what their violence, how much area they cover, how fast they are moving, and what direction they are following.

More and more information regarding storms is being supplied for aircraft by wire line and radio communication.

*Part of Symposium on Electrical Measurement of Non-Electrical Quantities.

†Consulting Engineer, Brooklyn, N. Y.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

The devices to be used for that purpose are the radio apparatus on ships, radio and wire apparatus on land, and, to some extent, the cables under the seas.

In connection with water navigation, the life and property saving ability of the radio S. O. S. call forced the use of radio on practically all large ships, and for some years, the position of icebergs and other menaces to navigation have been regularly reported to ships by the same radio communication that is used for other purposes.

There are special electrical aids which will bear some description; such, for example, as the earth inductor compass, the radio compass, and the depth finder.

There is some relationship between the old magnetic compass and some of our more modern aids. The magnetic compass, the earth inductor compass, the radio compass, and the compass used to follow an energized cable in a channel are all magnetic flux indicators.

Earth Inductor Compass

The earth inductor compass is the device most closely related to the old magnetic compass. In an airplane, the compass must be close to the pilot or navigator, where he can see it. But there may be iron nearby which makes the magnetic compass inaccurate. The revolving coil of the earth inductor compass may be located at some distance from interfering iron and the current from it can be conducted to a galvanometer located where the pilot or navigator can see it.

The earth inductor compass is a d-c. dynamo in which the magnetic field is supplied by the earth. By reference to Fig. 14 it will be seen that to cut the earth's north-to-south field, a windmill at the top revolves a one-turn armature winding connected to a commutator, and that the brushes connect to a meter. It will also be noted that the position of the brushes may be shifted. The meter is a d-c. galvanometer; therefor if the brushes are set in one position, a maximum deflection will be obtained when the windmill is turning the armature rapidly. With the brushes moved to a position at right angles, no deflection will result.

If the device is mounted on an airplane, the plane headed in the direction it is to follow, and the brush controller turned to produce no deflection on

the galvanometer, there will be no deflection so long as the plane continues in that course. If the airplane turns off course to the left, the galvanometer pointer will move to the left; and vice versa if the plane heads to the right. Should the airplane be turned completely around, the galvanometer pointer will move to the right when the plane moves to the left.

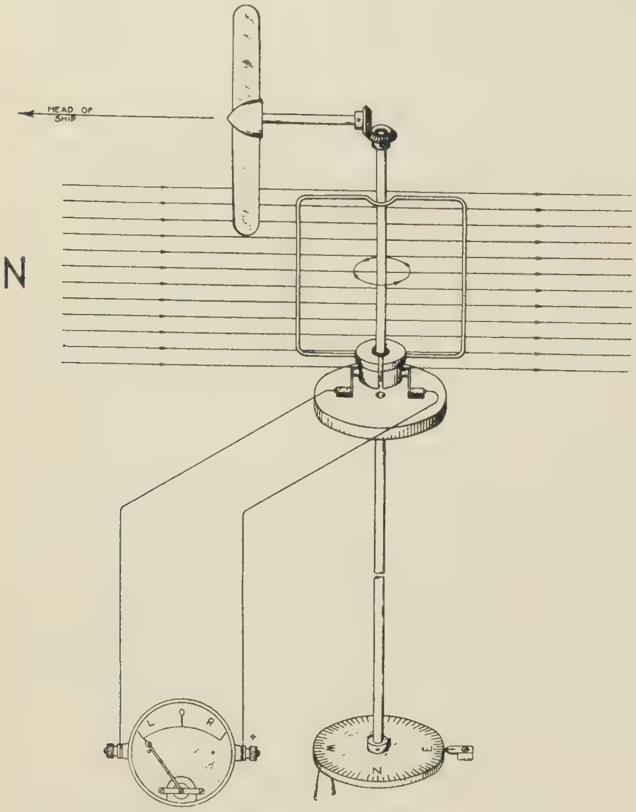

Fig. 14—Schematic Representation of the Earth Inductor Compass

Radio Compass

A radio compass, direction finder, or goniometer, is a radio receiving device which permits determination of the line of travel of waves as received from a transmitting station.

The radio compass must be carefully built, properly located, calibrated under service conditions, and corrected to suit the peculiarities of its location. When these things are done, a good degree, and sometimes a remarkably fine degree, of accuracy is obtainable. Otherwise the radio compass is much like the loop type of broadcast receiver with which many are familiar and with which good or poor directional effects may be obtained depending on the receiver and the location.

The loop antenna, or radio compass, is not new. It is sometimes called the Hertz loop. But as the energy in it depends upon phase difference, the energy is small as compared to the energy in an open antenna. It was the amplifying ability of the vacuum tube that brought the loop back into use long after the days of Heinrich Hertz.

In the United States, the Navy Department maintains radio compass stations at suitable points along the coast lines. All navigators have the exact location of these compass stations on their charts. When a ship wants a bearing during thick weather, it calls for a navy compass station, the compass station replies and asks the ship to transmit for a sufficient interval for the compass station to get the ship's bearing relative to the compass station. This information is then transmitted to the ship.

In Europe, similar compass stations are located along the lines of air travel. These keep following the craft in the air, and tell them by radio telephone where they are.

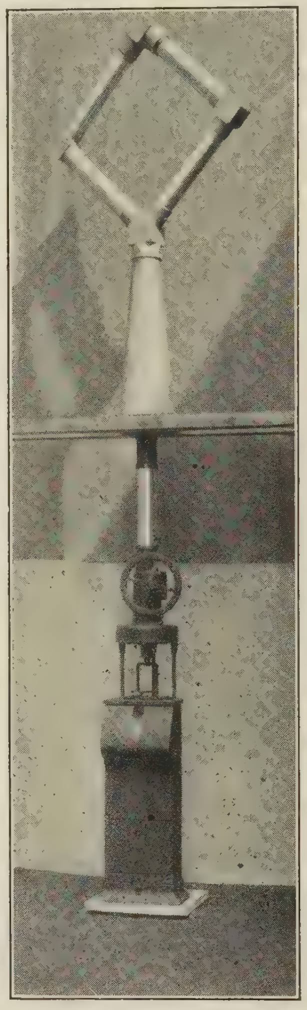

Fig. 19—Steamship Type of Radio Compass

Fig. 19 shows a type of radio compass used on steamships. The hollow square at the top is a tube containing the turns of the compass loop. That square portion is above the top of the pilot or chart house, and is sturdy to withstand weather. The loop is turned by the hand wheel shown below.

Radio Beacon

A radio beacon is a radio transmitting station in a fixed geographic location which emits a distinctive or

characteristic signal for enabling mobile receiving stations to determine bearings.

Such a beacon may transmit in all directions, or chiefly in one, two, or four directions; or it may be directive and revolve, giving different indicating signals for different directions. When the beacon transmits equally in all directions, a radio compass is necessary for the receiver to determine the direction of the beacon from the receiver. The direction of a revolving or fixed directive beacon may be determined by the receiver without the use of the radio compass.

For aviation, low power marker beacons which radiate in all directions but give a characteristic signal are located along air routes. If the flyer sticks to his course, he will hear them, one after another, as he flies near them. Directly over them, he will not get a signal from a vertical antenna. The combination of marker beacons, directive beacons, and weather reports by radio telephone, can be of great assistance to the flyer who has no space for long range receiving apparatus and a radio compass.

A visual device is mounted on the board in the front of the pilot. It operates something like a reed type frequency meter. A beacon station sending two signals at two angles and modulated to the frequencies of the reeds can cause one reed to vibrate farthest when the aircraft is off the course on one side; the other to vibrate farthest when off the other side; and both to vibrate the same amount when he is on the course.

Submarine Signal

The electrical submarine signal transmitter is a large tuned steel diaphram driven by alternating current. The submarine signal receiver is, in its simplest form, a small diaphram and microphone button, like a telephone transmitter, connected through a battery to a telephone receiver.

The submarine transmitter, for example, is suspended below a light-ship and actuated by groups of short and long signals that are characteristic of that light-ship. All vessels equipped with submarine receivers can pick up those characteristics signals through the water when the light-ship cannot be seen through fog, or when a sound could not be heard over the same distance through the air.

In this way, such signal shave been heard as far as 80 miles. There are numerous submarine signal transmitters of the pneumatic bell and electrical types, and probably over two hundred steamship lines have equipped their vessels with submarine signal receivers.

Depth Finding

Echo depth sounding, the sonic depth finder, and the fathometer all refer to the same principle; namely, sending a submarine signal from a vessel and receiving on the same vessel the sound or echo that is reflected from the bottom.

The submarine transmitter is attached to the vessel's hull and consists of a large tuned steel diaphram driven by alternating current. The signal sent is of short duration to prevent its interference with the reflected sound or echo.

The receiver, sometimes called a hydrophone, is a telephone transmitter immersed in a small enclosed metal tank of fresh water on the ship's hull at some distance from the transmitter (Fig. 26). The telephone transmitter is connected through its source of direct current and a filter for reducing other sounds to a vacuum tube amplifier which operates a relay. The relay through an electrically energized transformer causes a neon Geisler tube *A* to glow when an echo is received. The motor-driven Geisler tube revolves like a pointer back of a scale that is transparent at its edge. The scale is calibrated in fathoms. The Geisler or neon tube pointer makes a revolution in one-quarter of a second and every time it passes zero the transmitter is operated by *B*. Sound travels about 4800 feet or 800 fathoms per second; therefore the neon

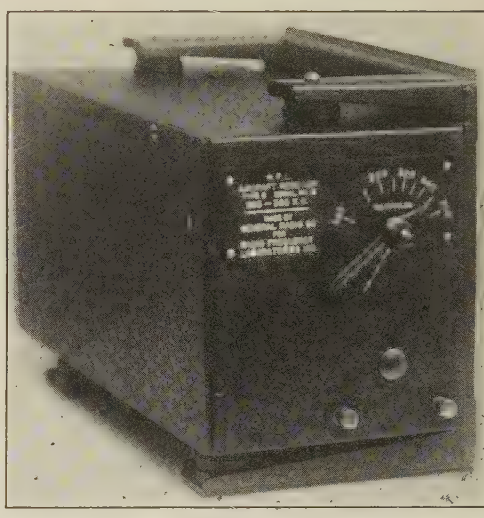

Fig. 24—Airplane Receiver for Radio Beacon and Telephone

pointer will travel for one-eighth of a second or half way around the scale while the transmitter sound is traveling 100 fathoms or 50 fathoms to the bottom and 50 fathoms back as an echo and the neon tube will glow as it passes the 50-fathom mark on the scale.

Combined Submarine Sound Beacon and Radio Beacon

In this, the submarine signal transmitters and receivers as described above are used in cooperation with a radio beacon transmitter and receiver. The receiving ship's officer listens with head phones that are connected to both a submarine receiver and a radio rereceiver. He hears the radio signal almost instantly and presses a button that starts a clock. Later he hears the submarine signal and presses the button again, stopping the clock at a figure which corresponds to the number of nautical miles between his ship and the light-ship.

Possible and Probable Electrical Aids to Navigation

There are several electrical schemes which may prove to be valuable for use as aids to navigation,—schemes that range all the way from those which have been tried and seem to be practical to schemes that may be only visionary.

For example, a device that will enable vessels to navigate a narrow crooked channel in fog has been demonstrated on large transatlantic liners and naval craft by the U. S. Navy Department in New York Harbor. By the device, a blindfolded helmsman could follow a channel. The device is comparatively simple. The transmitter includes a single-conductor cable laid in the bottom of the channel, through which alternating current of say one thousand cycles is conducted to its outer end, which is grounded. The receiver on a steel vessel includes two flat coils of wire hung on the port and starboard sides of the ship, parallel to the ship's sides and connected to two head phones or other indicators. When the keel of the ship is steered directly over the cable, the responses from the two coils will be equal. When the ship gets off on the starboard side, the greatest response will come from the port-side coil and vice versa, until the ship is brought back to where it should be. A single coil in gimbals can be used on wooden ships, (Fig. 29).

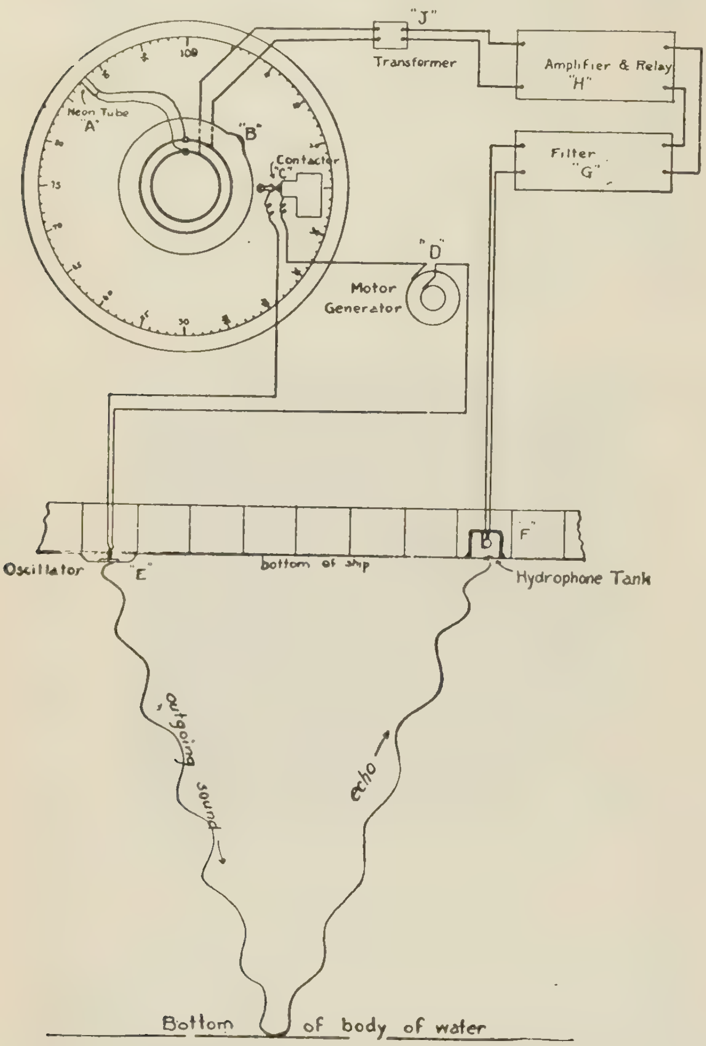

Fig. 26—Schematic Representation of the Mechanics of Depth Finding

One cable carrying a distinctive signal, even speech, can be used for incoming vessels and another for outgoing vessels.

Such a device has been proposed time and again, and our Navy spent a great deal of money in demonstrating its practicability. However, the device is not used, even in such an important channel as that leading to New York. Its lack of use seems to stand as a criticism of the traditions and principles of water navigation.

It has been proposed also to use this same scheme for guiding aircraft across the country. In France such a conductor has been installed on a pole line.

It is proposed to use several high-power Geisler types of tubes producing light which will penetrate farther through fog than ordinary light will penetrate.

Fig. 29—Locating the Position of a Channel Cable

In which a 1000-cycle current is flowing, by turning and tilting a single coil on a wooden vessel

Also it is proposed to use the photoelectric cell, which is more sensitive than the eye to the light rays that penetrate fog. The effect on the photoelectric cell is to be amplified to operate an indicator such as a galvanometer.

Aviators are provided with barometers to indicate their height above sea level; but that is not an indication of their height above the ground unless they know where they are and know the height of the ground

below them. Several devices have been proposed therefore to measure height above the ground.

As aircraft make a great deal of noise, it is proposed to produce on those craft sound signals which are higher in frequency than any of the sounds produced by the aircraft and pick up those signals after reflection from the earth, by means of an indicating device tuned to their frequency. That scheme is similar to the depth finder used in water navigation except that higher sound frequencies are proposed.

Another scheme involves the transmitting of radio waves to ground and picking up their reflection on the aircraft. The strength of the reflected signal may work out to be the factor for indicating height or the phase relation of the outgoing frequency to the reflected frequency may give the altitude in terms of the radio wavelength.

Over a radio beacon using a vertical antenna the aviator probably could estimate his height by the diameter of the dead area directly above the station.

The variations of the air dielectric of a condenser with altitude has been proposed as a substitute for a barometer.

For illustrations and other assistance in the preparation of this paper I wish to thank Dr. J. H. Dellinger of the U. S. Bureau of Standards, Dr. Louis M. Hull of the Radio Frequency Laboratories, Mr. Haraden Pratt of Mackay Radio & Telegraph Co., Mr. Malcolm P. Hanson of the Naval Research Laboratory, Mr. G. W. Pickard of the Wireless Specialty Apparatus Company, Mr. Victor E. Carbonara of the Pioneer Instrument Company, Mr. J. E. Colloton of the Submarine Signal Corporation, and the Institute of Radio Engineers.

Abridgment of

Study of Noises in Electrical Apparatus

BY T. SPOONER*
Member, A. I. E. E.

and

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Associate, A. I. E. E.

Synopsis.—*The objections to unnecessary noises in electrical apparatus are becoming so insistent that the manufacturers are making every effort to reduce them. In order to attack the problem intelligently it is first necessary to determine the amplitude and frequency of the components of the complex sounds. The first requirement then is a simple portable sound analyzer. Descriptions are given of the resonance types which have been developed. There is included also a short discussion of the laws of sound variation and sound units. Finally there are discussed various applications of the sound analyzer to the study of noises in gears, motors, generators, induction regulators, loud speakers, vacuum sweepers, and the like.*

* * * * *

STUDY OF NOISES IN ELECTRICAL APPARATUS

Introduction. Psychologists have found that noise reduces human efficiency. This effect may be very considerable even for the most phlegmatic individuals. Moreover, most of us object to unnecessary noises. In recent years there has arisen a very insistent demand for quieter electrical apparatus. This applies particularly to household apparatus such as refrigerator motors, vacuum sweepers and the like. In order to attack intelligently the problem of reducing noises, it is first necessary to study them in detail and resolve them into their components.

That the human ear is very inadequate for such purposes is well known. Two examples from our own experience will serve to illustrate this. A few years ago nine loud speakers, practically alike, were mounted at one end of a long hall with an observer stationed at the other end. This observer was unable to tell with certainty whether or not one of these loud speakers or all nine were operating. Ordinarily the human ear can detect much smaller differences in sound volume than this, but the illustration serves to show that under certain circumstances, the ear is a very poor judge of sound intensity. The second illustration has to do with the estimate of frequency. A certain member of the laboratory staff has a very good sense of absolute pitch. If a note is struck on the piano, this individual can tell usually what note it is and give the corresponding frequency in cycles per second. In a noise proof room there was under test a compressor motor which was very noisy, the frequency of this sound corresponding to the number of stator teeth. The above mentioned observer was asked to listen to this motor and make a guess concerning the frequency of the noise. He stated that the motor had two frequencies, one at about 350 and another at 450 cycles per second. As a matter of fact there was only one frequency of any magnitude and this was 900 cycles per second. This shows that one's judgment of frequency may be very poor for unaccustomed sounds. Many have known of cases where an inspector has rejected a machine one day because of noise and the next day passed the same machine without any change in the apparatus having been made in the mean time. Such a thing may happen because the room noises were greater on the second day than on the first or perhaps simply because the inspector had had a good

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breakfast or for some other reason was in an amiable frame of mind.

Sound Analyzers

Various devices for measuring the sound components of recurrent phenomena have been developed. The analyzers used for the investigations about to be described were of the simple resonance type. Other analyzers using different methods and usually much more complicated have been built and used where it

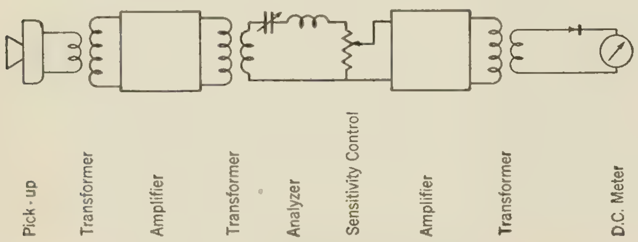

Fig. 3—First Noise Analyzer

was not essential that the analyzers be portable. Figs. 3 and 4 show diagrammatically two types of analyzers which have been constructed. Referring to Fig. 3, the pick-up consists of an electrodynamic microphone feeding into a step-up audio-frequency transformer, vacuum-tube amplifier and step-down transformer. The resonant circuit of the analyzer consists of a fixed inductance and variable condenser. The voltage across the non-inductive resistance with a variaple tap is fed into a second amplifier, a step-down transformer and a d-c. milliammeter and copper oxide rectifier. Obviously, if a sound having a frequency com-

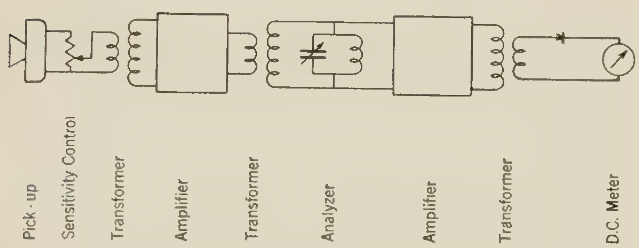

Fig. 4—Second Noise Analyzer

ponent corresponding to the setting of the resonant circuit impinges on the microphone, a reading will be obtained on the d-c. meter. If the analyzer circuit is not in resonance it will offer such a high impedance that the particular frequency in question will not produce sufficient current in the analyzer circuit to produce an appreciable drop in the non-inclusive resistance. The second type of analyzer (Fig. 4) is similar to the first except that the sensitivity control is transferred to the microphone circuit and the analyzer circuit is arranged differently. In this case the resonant arrangement provides practically a short circuit for the secondary of the second transformer except when tuned to the incoming frequency. When the tuning corresponds to a certain component of the sound frequency, the analyzer circuit offers a high impedance to this frequency and an appreciable voltage is applied to the input of the second amplifier. The rectifier for this second analyzer makes use of a vacuum tube rather than a copper oxide rectifier. The second analyzer gives a meter reading which varies very considerably with frequency for a given sound pressure. This is no serious disadvantage, however, since the analyzers are calibrated over the whole range of frequency.

Applications

We shall now proceed to describe certain typical applications for the analyzers which have been made.

I. *Gears.* One of the first applications made of the noise analyzer was for the purpose of studying electric railway motor gear noises. These noises are of three general types:

a. Ringing noises which are the same as those which appear when a gear is struck with a hammer.

b. Tooth frequency noises.

c. Hobbing noises which are a result of imperfections in the gear cutting machine.

The ringing noise occurs only at no-load. This

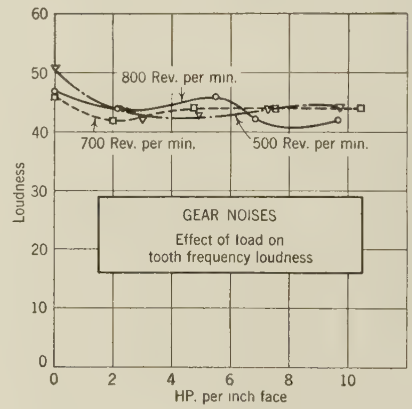

Fig. 6—Gear Noise Tests

can readily be noted frequently when the power is shut off and a trolley car is running down hill. The frequency is usually of the order of from 1000 to 2000 cycles per second. If the gear is struck with a hammer when stationary its ringing frequency may be determined by means of a noise analyzer. The frequency of pinions is usually so high as to be above the audio range. This ringing noise can easily be eliminated by a method devised by Mr. R. E. Peterson which will be described in a paper soon to be published by him.

When the gears are running there is given forth a noise having a frequency which is proportional to the gear speed and number of teeth. The pitch is usually much lower than the ringing frequency.

If the master gear on the gear cutting machine has imperfections in the teeth, which sometimes occurs, the gears which are cut by this machine will have a frequency when running corresponding to the r. p. m. and number of teeth on the gear cutting machine. This is known as the hobbing noise.

If a set of gears is put in operation and the various frequencies determined by the analyzer, it is very easy to determine which gear or gears is responsible for the noises because the ringing and tooth frequencies are already known or can easily be determined. Any other frequency must be due to imperfections in the cutting of the teeth. Figs. 6, 7, 8 and 9 show some typical gear

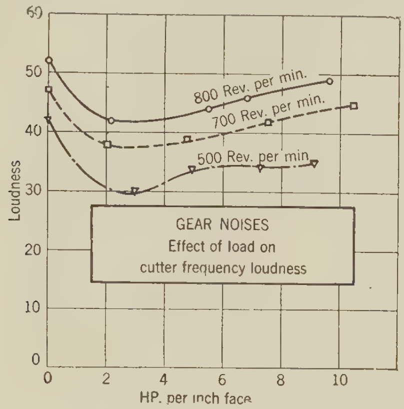

Fig. 7—Gear Noise Tests

noise tests made on commercial somewhat imperfect gears as a function of load and frequency.

Electric Motors and Generators. There are several causes of noise from rotating electrical machines as follows:

a. Tooth frequency noises (stator and rotor).
b. Windage (fans).
c. Natural period of frames.
d. For single-phase motors, variations in torque and forced frame vibrations.

In induction motors having rotor slots there is nearly

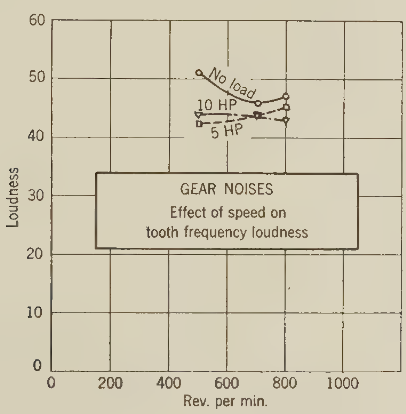

Fig. 8—Gear Noise Tests

always an appreciable amount of vibration which is proportional to the number of stator and rotor teeth and the rotor speed. These noises are the result of reluctance pulsations which produce vibrations of the teeth and sometimes the frame. Often these noises are very considerably increased as the load becomes larger. An interesting case of magnetic noise recently came to our attention in connection with a salient pole synchronous machine. This machine produced a very considerable noise having a frequency corresponding to the number of stator teeth and the rotor speed. An analysis showed that the pole width and stator slot pitch were such that at one instant practically three teeth were under the pole and an instant later when the pole had advanced one-half a stator slot pitch practically four teeth were under the pole. This gave rise to very appreciable reluctance pulsations between the rotor and stator. This condition probably would not have produced any appreciable noise if it had not been for one further unfortunate circumstance. The pole pitch was such that at a certain instant several adjacent poles were subjected to approximately minimum reluctance conditions and then an instant later to maximum reluctance. This resulted in a very considerable frame vibration having the frequency noted above.

When motors are supplied with ventilating fans it is quite usual to obtain appreciable noise which is a

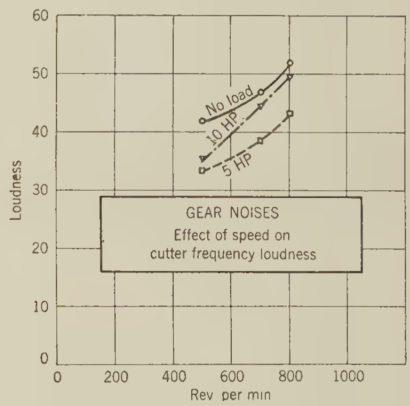

Fig. 9—Gear Noise Tests

function of the motor speed and the number of blades on the fan. This is known as the siren frequency and often consists not only of the fundamental but also of harmonics. Other portions of the rotor also may produce siren frequencies.

It occasionally happens that a machine may be operated at such a speed that some frequency component may be very close to the natural period of the frame or some other portion of apparatus. In this case noises may be produced which are considerably in excess of those which occur at some slightly different speed. A slight change in speed will reveal such a condition.

Single-phase, 60-cycle motors almost always have appreciable 120-cycle noises. These are due to torque variations or to frame vibrations. Also not infrequently harmonics of 120 cycles may appear.

In studying noises from small motors where the sounds are of no great magnitude and the microphone is placed close to the motor, care must be taken to shield the microphone from stray fields or to keep it sufficiently far removed from the apparatus under test. Otherwise, odd harmonics of the voltage will appear in the analyzer which are not caused by the sound.

Induction Regulators. For 60-cycle regulators sound analyses so far as we have observed will always show that the frequency consists mainly of a 120-cycle component. In the past it has usually been thought

that when a regulator was particularly noisy the causes were dissymmetry in the magnetic fields and loose bearings. Recently some three-phase regulators were studied to determine the source of the noise by means of the vibration apparatus mentioned above. The phonograph pick-up and amplifier were connected to one element of an osiso, a second element being operated from the exciting current of one of the phases in order to supply a phase reference point. Vibration measurements on the rotor and various parts of the stator disclosed the fact that the rotor movements were much less than the stator vibrations and there were no appreciable torque vibrations. It was disclosed that the stator punchings and frame assumed an elliptical form, the ellipse revolving with the rotating field.

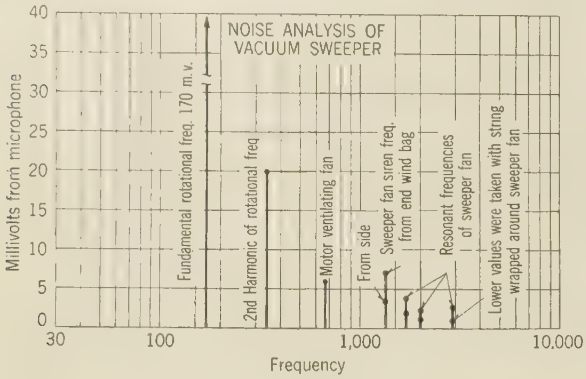

FIG. 10—NOISE ANALYSIS OF VACUUM SWEEPER

Obviously then the method of minimizing the noise from this particular type of regulator was to stiffen up the stator punchings and frame.

Vacuum Sweepers. These household devices operate at a very high speed, usually of the order of 10,000 r. p. m. The various principal causes of noise are as follows:

a. Sweeper fan noises.
b. Motor and ventilating fan noises.
c. Unbalance.

Figs. 10 and 11 show noise analysis results on a well-known vacuum sweeper. Fig. 10 gives the noise components as a function of microphone millivolts which are proportional to sound pressures and Fig. 11 gives the same data as a function of loudness units. (See Fig. 2). It will be seen that in terms of loudness units the higher frequency components are much more important than would be indicated from the sound pressure spectrum, due to the greater sensitivity of the ear at the higher frequencies. It was found by striking the fan, thus causing it to vibrate and measuring the frequencies with the noise analyzer, that the sweeper fan had three natural frequencies corresponding to three different modes of vibration. It will be seen from the spectrum that under operating conditions all of these frequencies appeared to be giving comparatively large noise components. Of course the siren frequency of the sweeper fan was a rather large percentage of the total noise. The motor ventilating fan gave a surprisingly loud noise considering the fact that it was much smaller than the main sweeper fan. The particular sweeper under test was not very accurately balanced; therefore, a very large frequency component of approximately 170 cycles resulted. This corresponds to a rev. per min. of approximately 10,000. Also there appeared a very appreciable second harmonic of the rotational frequency.

Obviously if an attempt were made to alter this sweeper so that it would be quiet it would be of very little use to reduce any one component to a small value because the total noise could thereby be decreased only slightly. The production of a really quiet vacuum sweeper is a problem of no little difficulty.

Conclusions. We might enumerate other examples of noise analyses but those given are sufficient for illustration. The quantitative determination of noise is very difficult even with an analyzer due to nodes and sound reflections. Noise often varies very greatly in different locations around a piece of apparatus and it varies with the position of the objects in the room. For the accurate study of noise, the apparatus should be taken to a sound proof room with deadened walls so that there will be little reflection. However, in a large number of instances where only one or two frequency components are important qualitative results are quite sufficient. In other cases when tests must be run under shop conditions only qualitative results can be obtained due to a large amount of reflection as well as interference from the shop noises. In these cases results can be obtained very quickly by means of the analyzer by using head phones in place of the meter usually used to measure amplitude. Then even though the surrounding noise level is very high it is possible to obtain accurate frequency determinations of the noise being studied. Usually if the frequencies of the principal components can be determined the cause or causes of the noise can be assigned and means taken to eliminate or reduce it. Therefore, a qualitative test is very often sufficient to enable the designer to avoid similar conditions in future apparatus.

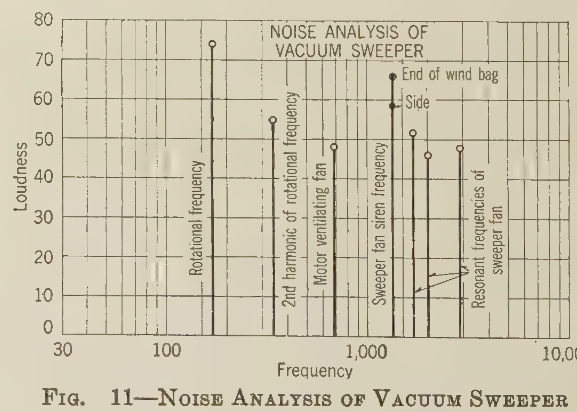

FIG. 11—NOISE ANALYSIS OF VACUUM SWEEPER

We are greatly indebted to Mr. R. E. Peterson who has given considerable assistance and many valuable suggestions in the work on gear noise. We also wish to acknowledge the assistance rendered by Mr. C. F. Royce in certain phases of this work.

Abridgment of

Corona Ellipses

BY VLADIMIR KARAPETOFF[1]

Fellow, A. I. E. E.

Synopsis.—The purpose of this investigation is to give a mathematical theory of the cyclograms of corona obtained by a cathode ray oscillograph. In the case investigated a long wire of small diameter is connected to one terminal of an a-c. source; the other terminal of the source is connected to a concentric cylinder of considerable diameter, or to a metal plate at some distance from the wire. A cathode ray oscillograph with two pairs of deflecting plates, at right angles to each other, is so connected that one pair of plates causes deflections of the cathode beam proportional to the values of instantaneous voltage of the source, and the other pair of plates causes deflections proportional to the instantaneous values of the charging and loss current flowing into the wire.

So long as the sinusoidal amplitude of the applied voltage is below the visual corona point, the charging current is also sinusoidal, in time quadrature with the voltage. The oscillograph record is therefore an ellipse, with the amplitudes of the voltage and the current as the principal semi-axes. When, however, the minimum ionization voltage is exceeded during a part of each alternation, the cyclogram ceases to be an ellipse, but consists of four portions per cycle, two of which correspond to the intervals of time during which the corona is extinct, and the other two when corona is present, with quite short transients in between.

F. W. Peek, (A. I. E. E. TRANS., Vol. XLVI, 1927, p. 1009) published a number of such oscillograph records, with voltage amplitudes both below and above the visual critical point. In order to explain the mechanism of corona formation and the influence of the space charge upon the instantaneous critical voltage, he also produced "artificial corona," by using two condensers in series, one of which was shunted by a sphere-gap.

The purpose of the present investigation is to give a mathematical theory of the observed cyclograms, on the basis of two condensers in series, with the space charge as a fictitious dividing line. To account for the actual motion of ions and the power loss, the condenser nearest the wire is assumed to be shunted by a conductance, and to have a resistance in series. Approximate equations are derived for the current and the voltage as functions of time.

For the artificial corona it is shown that the composite curve consists of arcs of two ellipses, with their principal axes along those of the cyclograms. Assuming the visual critical voltage to be known, an expression is derived for the instant of the cycle at which the corona is re-established.

For the actual corona, it is shown that the cyclogram also consists of portions of two ellipses, only their principal axes are at some angles with the principal axes of the cyclogram. The theory is applied to one of Mr. Peek's records, and it is shown that both the shape of the experimental curves and the instants at which the corona is re-established check fairly well with the theory.

* * * * *

I. Introduction

NUMEROUS laboratory tests and theoretical researches on corona formation about long cylindrical conductors of comparatively small cross-section have been made by various investigators; many noteworthy results have been recorded in Institute papers for over twenty years. The modern cathode ray oscillograph, which is a further development of the original Braun tube, has made it possible to study the a-c. corona in much greater detail quantitatively,—from instant to instant,—and thus has brought us nearer a rational explanation of the ionic mechanism involved.

A number of a-c. corona records (cyclograms), obtained by means of a cathode-ray oscillograph, were published by Lloyd and Starr[2] and by Peek.[3] Peek's Fig. 9A is reproduced in Fig. 1, using a somewhat different ratio of the scales for abscissas and ordinates. The beam was slightly diffuse (not focused), and rather than to draw an arbitrary average line, the boundaries of the actual trace on the photograph are shown by the cross-hatched strip. The theoretical ellipses drawn in the same sketch do not concern us yet.

The horizontal distances from the vertical axis are proportional to instantaneous values of the sinusoidal applied voltage between the wire and a metal plate. The vertical ordinates represent the corresponding instantaneous values of the current flowing into the wire. The cyclogram refers to the established conditions, and is different from one for the first few cycles. The cathode beam traced the figure counter-clockwise.

Beginning at point p, where the applied voltage is zero and the corona is maintained by the previously accumulated space charge, (see Peek's paper for a physical explanation of this seeming paradox), we arrive at point b at which the applied voltage reaches its maximum. Shortly afterwards the flow of current stops and the corona is extinguished somewhere between the points b and s. On the decreasing voltage the corona is re-established at point h and continues until slightly beyond point d; $d\,k$ is again that portion of the next alternation during which the corona is extinct. It is re-established at point k. The two parts of the actual cyclogram, $p\,n\,b$ and $r\,q\,d$, are not quite alike, because of the difference in the mass and mobility of positive and negative ions.

The purpose of the paper is to outline a mathematical theory which explains the general shape of the observed corona cyclograms. The narrower of the two theoretical ellipses shown in Fig. 1 represents the current-voltage

1. Professor of Electrical Engineering, Cornell University, Ithaca, N. Y.

2. W. L. Lloyd, Jr., *Methods Used in Investigating Corona Loss by Means of the Cathode Ray Oscillograph*, A. I. E. E. Trans., 1927, Vol. 46, p. 997.

3. F. W. Peek, *The Law of Corona and the Dielectric Strength; ibid.*, p. 1009.

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relations during those portions of the cycle when the corona is extinct. The broader ellipse gives a similar relationship with the corona present. The theoretical transition points are indicated by the small circles at h and k. It will be seen that the agreement with the

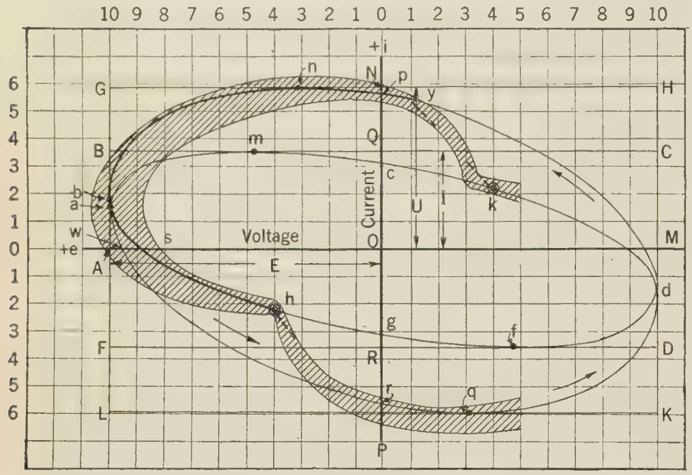

Fig. 1—An Actual Oscillogram of A-C. Corona (Peek) with the Corresponding Ellipses

observed cyclogram is quite satisfactory considering the complicated nature of the phenomenon.

II. Two Condensers in Series, One of Which is Shunted by a Spark-Gap

The Circuit. We shall consider first the circuit (Fig. 2) which, according to Peek, roughly imitates the conditions in an actual a-c. corona. This circuit consists of two condensers, C_1 and C_2, in series, the first one being shunted by a "glow-gap" G_1. In this ideal glow-gap, as distinct from an actual "spark-gap," a copious corona promptly takes place between the "hair brush"

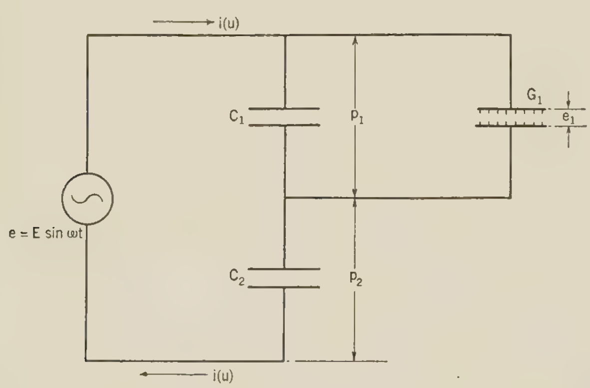

Fig. 2—Two Condensers in Series One of Which is Shunted by a Glow-Gap

electrodes when the voltage between them reaches a value e_1. When the applied voltage is raised further, the discharge remains corona-like at the same voltage e_1 and does not change to streamers or sparkover. The excess voltage is supposed to be consumed in the condenser C_2. The corona stops instantly when the voltage p_1 drops below e_1. We shall not discuss here the question as to whether such a gap is realizable in practise or not, because the circuit shown in Fig. 2 is intended merely as an analog, to simplify the mathematical treatment of an actual a-c. corona around a conductor.

We shall disregard the non-periodic transient conditions of the first few cycles, and assume the phenomenon to be periodic, as shown in Fig. 3. In this cyclogram, the cathode beam undergoes two harmonic motions simultaneously. One is along the axis of abscissas, and the deflections are proportional to the total applied voltage $e = E \sin \omega t$. (See notation at the end of the paper.) The other motion is along the axis of ordinates, the deflections being proportional to the instantaneous values, i, of the current through the condenser C_2. The cyclogram is described by the cathode beam counter-clockwise. The points of discontinuity correspond to the instants at which the current suddenly increases when the corona is reestablished. The corona is extinguished at the extreme

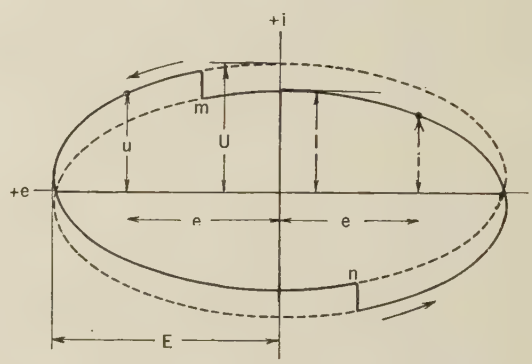

Fig. 3—An Actual Cyclogram (Peek) taken on the Arrangement shown in Fig. 2, with the Corresponding Ellipses

right and left points where the voltage reaches its maxima, because at these instants the current becomes zero and is reversed.

Because of these discontinuities, the cathode beam alternately follows two distinct curves, and it is necessary to consider the equation of each separately. In the original paper it is shown that both curves are arcs of ellipses.

III. Ellipses of Actual Corona

The proper scientific way to treat mathematically a d-c. glow discharge about a round wire is by determining the distribution of electric space-charge density and the voltage gradient as functions of the distance from the geometric axis of the conductor. This can be done by using the divergence theorem and considering the mobilities of ions. While the mathematics of such a deduction is quite complicated and some uncertainties and simplifications are unavoidable, Otto Mayr[4] has succeeded in obtaining approximate ex-

4. Otto Mayr, "Raumladungsprobleme der Hochspannungstechnik," *Arch. f. Elek.*, 1927, Vol. 18, p. 270.

pressions for d-c. corona is finite form. He also has shown that the relationship between the critical voltage gradient at the surface of the wire, and the values of mobilities of ions determined by separate experiments of a different kind, is in fair agreement with his theory.

The theory of the a-c. corona is much more involved, since the space charge and the velocities of ions are then functions not only of the distance from the axis of the conductor, but of time as well. Moreover, the phenomenon becomes dependent upon the frequency of the supply, since an ion which at 60 cycles may travel during one alternation from the inner wire almost to the outer cylinder, at 5000 cycles may be caught and reversed near the inner conductor. Although Mayr shows by rough computations (*ibid.*, p. 276) that the conditions at 60 cycles are qualitatively the same as with direct current, yet so far no rational theory covering this case has been worked out.

Our problem here is much more narrow; namely, to represent mathematically the general features of the appearance of corona cyclograms, such as shown in Fig. 1, and this is attempted in a semi-empirical way on the basis of two equivalent diagrams which are a generalization of that shown in Fig. 2. A mathematical investigation given in the original paper shows that these equivalent diagrams lead to an elliptical relationship between the current and the voltage, both during the portion of an alternation when the corona is present and when it is out. The two theoretical ellipses are shown in Fig. 1. They are oblique with respect to the current and voltage axes, and it will be seen that the actual cyclogram follows the outline of the two ellipses quite closely.

The points k and h, at which the corona is re-established, have been determined theoretically, and it will be seen that they agree with the experimental transition points.

IV. Conclusion

It has been shown that the general shape of corona cyclograms, such as in Fig. 1, may be adequately represented by arcs of two ellipses, whose equations can be derived from an equivalent diagram of the corona. It has been shown also that cyclograms of a circuit consisting of two condensers and a glow gap (Fig. 2) also consist of arcs of two ellipses. In the latter case the ellipses are "straight," whereas with the actual corona they are "oblique."

While experimental and theoretical work on the detailed mechanism of corona is going on, based on a statistical consideration of actual moving ions in the glow region, the computations and the point of view presented in this paper may be of some value in that certain fictitious "bulk quantities" (capacitances and resistances) are introduced which may be calculated from experimental data. Variations in these quantities with the conditions of the experiment may give an indication as to the corresponding changes in the state of the gas, changes which otherwise it may be difficult to measure or to express by numbers.

The particular equivalent diagrams used in this paper are perhaps the simplest and the crudest possible, so that the field is open for further refinements. For example, it is natural to assume that the space charge does not retain its position during an alternation, but contracts and expands, so that the values of the two capacitances, C_1 and C_2, vary harmonically with the time. However, such refinements will be of value only when suitable experimental material is available to check theoretical conclusions and when the cathode ray in an oscillograph can be better focused, so as to produce a much sharper record.

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"Your service has been very satisfactory and I appreciate the effort shown and shall highly recommend service to any other members who are anxious to improve their positions."

October 20, 1928

"I have your letter of October 18 regarding the forty dollar contribution which I made recently. I have always regarded the Employment Service as a sort of family affair within the ranks of the Engineering Societies and not as an ordinary employment bureau. For that reason I did not hold to the one and a half per cent when I made my contribution, but preferred to add a bit for good measure. I feel that I am especially indebted to your organization because of the long period of service you have given me and because of your thoughtfulness in telegraphing me when I had not specifically asked you to follow that procedure. I consider the extra dollars to be a rather feeble expression of my gratitude, but hope that I may sometime be of service to you."

July 15, 1928

"I would like to take this opportunity to express my appreciation of the work done by your Employment Service, which has within such a short time brought me into contact with a firm of repute."

July 3rd, 1928

"Thank you for the good leads you have given me in the past, and principally for my recent connection.

"I regret that an unusually early sailing date prevented me from calling on you before I left the States, because I most certainly owe you an expression of appreciation that a fee could not cover.

"I am quite sure to like my work here, and all that goes with it. It will give me an opportunity to save some money and get on a little more solid ground, and that is the main objective.

"So thank you again, for past courtesies."

Abridgment of

Losses in Armored Single-Conductor Lead-Covered A-C. Cables

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***Synopsis.**—Besides the copper loss and the dielectric loss, the losses occurring in single-conductor armored cables, whose sheath and armor are bonded and grounded at more than one point, are the circulating-current losses in the sheath and in the armor, and the additional iron losses in an armor of magnetic material. The circulating-current losses are due to the currents induced in the sheath and armor circuits by the fluxes linking these circuits when these circuits are closed by the bonds or grounding connections.*

The sheath and armor losses have been analyzed for a steel-wire armored cable, a copper-wire armored cable, a steel-tape armored cable, and a cable enclosed in an iron pipe, and have been compared with the losses occurring in a plain lead-covered cable without armor. The data used include test data and calculated values.

It is shown that a steel-wire armored 350,000-cir.-mil single-conductor cable with sheath and armor short-circuited by low-impedance bonds had a total loss (exclusive of dielectric losses), of 2.8 times the conductor loss, by test in a single-phase 60-cycle circuit at 4 ft. cable spacing, at 260 amperes. The corresponding loss in a similar cable without armor, with lead sheath short-circuited, was 2.4 times the conductor loss. Thus the steel-wire armored cable had an additional loss due to the armor of about 20 per cent. A steel-tape armor or an iron pipe surrounding a single-conductor cable usually introduces considerably higher losses.

Under the same condition, a cable similar to the steel-wire armored one but having an armor of copper wires has a calculated total loss (exclusive of dielectric loss) of only 1.3 times the conductor loss, the armor current being 92 per cent of the conductor current.

The reduction of losses due to diminished cable spacing in a single-phase circuit is shown. When the cable spacing is reduced from 10 ft. to 1 ft. the over-all losses for a steel-wire armored 350,000-cir. mil cable (exclusive of dielectric losses) are reduced about 8 per cent, while those for a similar cable with copper-wire armor drop only about 3 per cent.

The relative total annual costs of a steel-wire armored cable and of a similar copper-armored cable, both cables having a conductor cross-section of 350,000 cir. mils, were compared. In view of the lower operating cost of the copper-armored cable, it was found to have a lower total annual cost than that of the steel-wire armored cable at load factors above 60 per cent, the steel-wire armor having the advantage economically at lower load factors.

Introduction

IN THE following are presented the results of test data and of calculations on losses in certain armored single-conductor lead-covered cables arranged in a single-phase circuit. With the aid of the data, the effects of the chief design variables on the total losses, and on the principal loss components are briefly discussed. The relative merits of steel-wire armor and copper-wire armor are compared both in respect to losses and total annual costs at different load factors. In the full paper a calculating procedure is given for the determination of the circulating currents in sheath and armor circuits for a pair of cables in a single-phase circuit or for three cables in a symmetrical three-phase circuit (triangular spacing) with balanced currents. The calculating procedure is briefly explained here.

In analyzing the circulating currents in single-phase circuits, the sheaths and armors of the going and return cables are considered as bonded together at two or more points by short bonds of negligibly small impedance. Any circulating currents flowing through the earth by reason of the particular system of grounding employed are not taken into account, since the effect of such earth currents upon the total circulating-current losses will usually be sufficiently small to be negligible.

Circulating-Current Losses in Lead Sheath and in Armor

The circulating-current loss in the lead sheath is due to the circulating current induced in the sheaths of adjacent cables by the flux passing between the cables when the sheaths are bonded together or grounded at two or more points.

The armor circulating-current loss is produced in a similar manner by the circulating current induced in the armor circuit. In addition there will often be eddy-current and hysteresis losses in the armor to be considered separately.

The behavior of armored single-conductor cables in regard to losses due to circulating currents in lead sheath and in armor is similar to the known characteristics of unarmored lead-covered single-conductor cables carrying circulating current in the lead.

It is well known that for an unarmored cable, the sheath circulating current increases with spacing between going and return conductors and varies with the sheath resistance. At the maximum sheath current, equal to the full conductor current, (*i. e.*, for the hypothetical case of zero sheath resistance) the circulating-current loss is obviously zero. While the sheath current falls with increasing sheath resistance, the sheath loss first rises to a maximum, and then falls, again approaching zero at infinite sheath resistance. Therefore a particular sheath design for each cable and for each spacing gives a maximum sheath circulating-current loss. Values of sheath resistance higher or lower than this critical value will give lower circulating-current losses than those for the critical sheath resistance. For the types of cable usually encountered in practise, and at moderate spacings, the sheath resistance is above the critical value.

*All of the General Electric Company, Schenectady, N. Y.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

When an armor is added to an ordinary lead-covered cable, and when in a cable circuit both armor and lead sheath are bonded at two or more points, the armor is in multiple with the lead sheath. Thus, the addition of the armor is at least approximately equivalent to a lowering of the sheath resistance in so far as the sum total of circulating-current losses is concerned, neglecting the difference between sheath and armor inductances. Hence, if the lead-sheath resistance itself were not higher than the critical value, the addition of the armor would actually tend to reduce the total circulating-current losses. These considerations, of course, do not include the extra eddy-current and hysteresis losses in a magnetic armor. The approximation just given is only very roughly made and is not recommended for estimating losses in armored cables, because it does not take into account such factors as the difference between the inductances of armor and sheath circuits, and the effect of a magnetic armor on inductance values.

Fig. 1 shows how the circulating currents and circulating-current losses are affected by varying the spacing between cables from one to 40 ft. in a single-phase circuit for the steel wire armored cable A of Table I. The curves also show the distribution of the circulating currents and of the losses between armor and lead sheath.

The effects of various cable designs and cable operating conditions on losses will now be considered.

Losses for Different Kinds of Cable

The kinds of cable which are compared in regard to circulating currents and losses are, (a) steel-wire armored cable; (b) cable without armor; (c) copper-wire armored cable; (d) cable with iron-pipe armor; and (e) steel-tape armored cable.

Their constants are given in Table I. Circulating currents and losses are given in Table II. Loss values are given per 1000 ft. of cable in a single-phase circuit of two similar parallel conductors carrying equal and opposite currents at 60 cycles per second. The values are based on test results and on calculations as well.

The ordinary lead-covered cable without armor,—cable (b)—is seen in Table II to have a lead-sheath circulating-current loss 1.4 times the conductor loss at 4 ft. spacing between cables, making the sum of the losses (exclusive of dielectric loss) 2.4 times the conductor loss, the sheath circulating current being 150 amperes or 58 per cent of the conductor current.

If the same cable is equipped with a *steel-wire armor cable (a)* and if both sheath and armor are short-circuited by bonds of low impedance, as is usually the case in practise, the sheath and the armor carry lower currents and have smaller individual circulating-current losses than the one occurring in Case 1. The ratio of total loss (exclusive of dielectric loss) to conductor loss is 2.8 for this steel-wire armored cable at 4-ft. spacing, the armor eddy-current and hysteresis losses being only about 10 per cent of the total losses. Therefore it is seen that the steel-wire armored cable in question has a total loss less than 20 per cent in excess of the total loss of a similar but unarmored cable when both cables are operated with low-impedance bonds.

For the copper-wire armored cable (c) the combined sheath and armor losses (see Table II) are only about 30 per cent of the conductor loss, on account of the low armor resistance (9 per cent of the steel-wire effective armor resistance at 100 amperes and 60 cycles). The armor current itself is 92 per cent of the conductor current at the 4 ft. spacing. Hence the over-all losses for this cable, with sheath and armor bonded and grounded at several points, are only 1.3 times the conductor loss or only half as much as the over-all losses for a similar cable with the steel-wire armor described.

The preceding data and discussions indicate that the over-all losses in steel-armored cables with sheath and armor circuits bonded and grounded at more than one point can be kept within reasonable limits—*i. e.*, within values that are not far in excess of those for unarmored cables likewise bonded and grounded—provided the armor eddy-current and hysteresis losses are kept low. The principal means to this end are indicated by the data of Table II and are the following: (1) An armor design of individual wires wound with a large lay; (2) Low-resistance circulating-current circuits so as to keep the resultant magnetizing force at the armor low by means of a large demagnetizing effect due to large circulating currents.

A very material reduction in the permeability of the armor will also tend, as a rule, to reduce the armor eddy-current and hysteresis losses for given dimensions and otherwise fixed constants. However, a general rule for the permeability and resistivity requirements of armor material—with a view to keeping the over-all losses low—cannot be given, because changes in the values of armor permeability and resistivity have many-fold effects (*i. e.*, on armor resistance, sheath and armor inductance values, circulating currents in sheath and armor circuits and the resulting losses, and armor eddy-current and hysteresis losses).

Tests

Tests were made for measuring the circulating currents and the various loss components; (1) for a steel-wire armored 350,000-cir. mil lead-covered cable (cable A in Table I) and (2) for a plain copper 350,000-circular mil cable in an iron pipe (cable D in Table I). Attention is also called to the data in Table II on a 211,600-cir. mil single-conductor cable with steel tape armor, reported by Middleton and Davis, *Electrical World*, November 18, 1916, p. 1003.

The test method and equipment are indicated in Fig. 2. The test cable itself was 50 ft. long and was set up in a loop of parallel sides at 4 ft. center spacing. The bonds were carefully soldered.

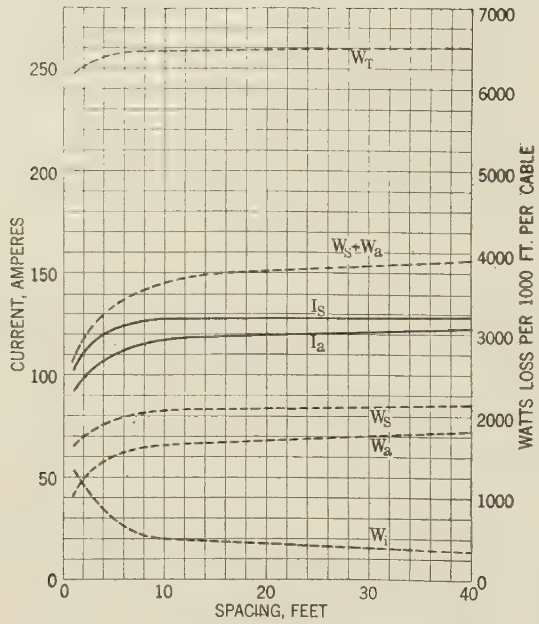

Fig. 1—Calculated Sheath and Armor Losses *vs.* Spacing

Single-phase circuit for cable A (see Table I)
Conductor current 260 amperes at 60 cycles per second
I_S = Sheath current
I_a = Armor current
W_S = Sheath circulating-current loss
W_a = Armor circulating-current loss
W_i = Eddy-current and hysteresis loss in armor iron
W_T = Total loss including copper loss and dielectric loss. Copper loss = 2080 watts. Dielectric loss = 150 watts

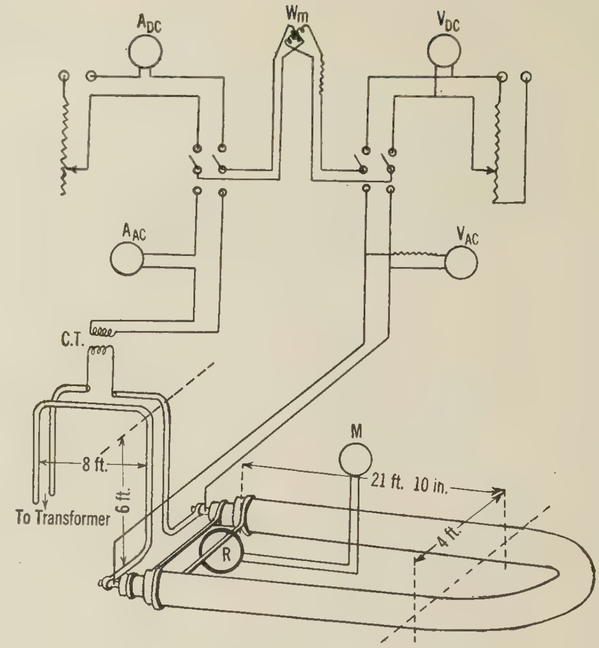

Fig. 2—Schematic Diagram of Test Set-Up and Test Circuits

A_{DC} = D-c. ammeter
V_{DC} = D-c. voltmeter
A_{AC} = A-c. ammeter
V_{AC} = A-c. voltmeter
W_m = Wattmeter
M = Thermocouple type milliammeter
R = Rogowski coil
$C.\ T.$ = Current transformer

TABLE I
DIMENSIONS AND CONSTANTS OF CABLES

	Cable A steel-wire armored	Cable B unarmored	Cable C copper armored	Cable D in iron pipe	Cable E steel tape armored
Voltage rating (line-to-line kilovolts)	44 kv.	44 kv.	44 kv.	....	....
Diameter of copper conductor—inches	0.682	0.682	0.682	0.682	0.528
Copper conductor cross-section in circular mils	350,000	350,000	350,000	350,000	211,600
Resistance of copper conductor per 1000 ft. at 25 deg. cent. in milliohms	30.8	30.8	30.8	30.8	50.9
Inside diameter of lead sheath	1.888	1.888	1.888	no lead sheath*	0.688
Thickness of lead sheath	0.13	0.13	0.13	no lead sheath*	0.086
Diameter over lead sheath	2.148	2.148	2.148		0.86
Armor type and description	single layer steel wire armor	no armor	single layer copper wire armor	2-in. iron pipe	double layer steel tape armor†
No. of armor wires (bands)	32	..	32	....	2 bands each 1 in. wide
Diameter of armor wires (thickness of bands)	0.18 in.	..	0.18 in.	....	0.035 in. thick
Lay of armor wires (bands)	10 times the armor dia.	..	10 times the armor dia.	....	1 in.
√ d-c. ohms/cm.³ for armor	15.4×10^{-6}	..	1.76×10^{-6}	13.8×10^{-6}	....
μ max. by d-c. for armor	770 at B = 7500 gausses	..	1.0	1260atB = 6300 gausses	....
Diameter under armor. in	2.398	..	2.393	2.0	1.03
Diameter over armor. in	2.758	..	2.758	2.375	1.17
Lead sheath resistance per 1000 ft. at 25° C, in milliohms	128	128	128	68.5*	505
Effective armor resistance per 1000 ft. in milliohms	120 at 100 amp. induced armor current	..	10.72	....	....
Calculated armor d-c. resistance per 1000 ft. 25 deg. cent. in milliohms	94	...	10.72	50.5	....

*Copper secondary conductor representing the lead sheath consisting of two rectangular conductors in multiple, each 0.485 × 0 125 in., placed along side the primary cable within the iron pipe

†The two tape layers wound in opposite directions.

TABLE II

Circulating currents and loss data per 1000 ft. of cable in single-phase circuit, for various kinds of cable operated both with and without bonding (or grounding) of sheath and armor. Conductor current = 260 amperes (except cable E which had 225 ampere) at 60 cycles per sec. Dielectric loss is not included. Bonds are considered to be of negligible impedance. Cable constants given in Table I.

Item	Cable	Test condition	Circulating currents amps. Lead sheath	Circulating currents amps. Armor	Conductor loss watts	Sheath circul. current loss watts	Armor circul. current loss watts	Armor eddy current & hyst. loss watts	Sum of losses watts	Ratio Total loss■ / Conductor loss	Cable spacing ft.
1*	A steel wire armor	Sheath & armor open no circulating currents	0	0	2080	0	0	2740	4820	2.3	4
2*	A	Lead sheath shorted armor open	185	0	2080	4380	0	1040	7500	3.6	4
3*	A	Lead sheath open armor shorted	0	136	2080	0	2220	1460	5760	2.8	4
4*	A	Both lead sheath and armor shorted	117	106	2080	1750	1350	600	5780	2.8	4
4a†	A	Both lead sheath and armor shorted	123	110	2080	1930	1460	550	6020	2.9	4
5†	B Cable without armor	Lead sheath shorted	150	0	2080	2880	0	0	4960	2.4	4
6†	C Copper wire armor	Lead sheath and armor shorted	23	240	2080	68	620	0	2768	1.3	4
7*	D iron pipe armor	Copper wire secondary circuit & pipe circuit shorted	195‡	42	2100	2680‡	3460		8240	3.9	4.5
			Conductor current 225 amperes at 60 cycles per sec. From tests by W. L. Middleton and E. W. Davis. *Elec. Wld.* Nov. 18, 1916, p. 1003								
8	E Steel tape armor	Lead sheath and armor shorted	168	22	2580	14,250	15,000		31,820	12.3	4
8a†	E	Lead sheath and armor shorted	185	21	2580	16,450	1220	7680	27,930	10.8	4

*Values based on test data adjusted for 25 deg. cent. temperature and corrected for resistance and reactance of bonds. The results for the cases having circulating currents thus apply to cables having bonds of negligible impedance.

†Values for items 4a, 5, 6, and 8a were calculated.

‡In copper wire secondary representing the sheath.

■Not including dielectric loss.

Circulating currents were measured by means of a Rogowski coil* with a thermocouple type milliammeter, the complete unit being capable of ready calibration when the coil was placed around a conductor carrying a known current. The Rogowski coil was used in order that the extra impedance due to the current-measuring device be negligible in circulating-current measurements.

Losses were measured by an astatic reflecting dynamometer wattmeter. All tests were made at 60 cycles.

Calculation of Losses

A loss-calculating procedure for determining the losses in single-conductor armored cables in a single-phase circuit, or in a balanced three-phase circuit with equilateral spacing has been established The procedure involves (a) the calculation of the circulating currents in sheath and in armor by formulas derived, which take into account the effect of armor iron on reactance values, (b) the computation of the circulating-current losses as $R I^2$ values, (c) the determination of the extra iron losses in the armor with the aid of suitable test data, or by calculations when sufficiently reliable. Test data on effective armor resistance and on extra iron losses were obtained for a steel wire armored cable. These data are applicable to loss calculations for certain steel-wire armored cables. Corresponding test data for cables with steel tape armor or with other types of magnetic armor have not been obtained. In the absence of these test data the calculations of the losses in steel tape armored cables are less reliable.

*An air-core current transformer looped around the particular current to be measured. See Rogowski, W. S., Steinhaus, W., "Measuring the Magnetomotive Force," *Arch. für Elek.*, 1912-1913, pp. 141 and 511.

The accuracy of the calculating procedure is indicated in Table II. For instance, the calculated current values for cables A and E in Table II are seen to be within 5 per cent and 10 per cent, respectively, of the test values, and the agreement between calculated and test values of overall losses is within 5 per cent and 15 per cent respectively. For the steel tape armored cable the predicted values of armor eddy-current and

hysteresis losses are considerably in error, indicating that in cases where the extra iron losses are a larger part of the overall losses, the calculations may be rather uncertain.

Economic Considerations

A submarine cable is usually furnished with an armor for mechanical protection and to prevent undue strains on the sheath while the cable is being laid and afterwards. It is customary to use a steel-wire armor rather than a band steel armor (which has inherent high losses); but it is also possible to obtain all the necessary mechanical strength with a copper armor.

The losses in the armored submarine cable will not affect its rating appreciably, because the armor throughout its length is in contact with the water which will keep the cable cool. It is thus apparent that the choice between a steel and a copper armor rests primarily on the economics of the situation.

Using cable a in Table I as a basis it was found that at low load factors the steel-armored cable will tend to be the more economical than the copper armored cable, while at high load factors the reverse is true. At 58 per cent load factor the economy of the two types of cable tends to be about the same for a cable spacing of 4 ft. Above, say, 2 ft., cable spacing the percentage given will also apply approximately over a wide range of spacings.

Abridgment of

Power Transmission and Distribution

CONCLUDING REPORT OF THE 1927-1928 SUBCOMMITTEE

Synopsis.—*This report gives the latest data of the subcommittee on the subject of the protection of transmission lines against lightning by the use of overhead ground wires, special construction, etc. Reports of power companies are included and recommendations of the committee are submitted.*

* * * * *

Protection of Transmission Lines From Interruptions Due to Lightning*

As indicated in the 1928 Report of the Committee on Power Transmission and Distribution,[1] the subcommittee undertook to obtain more data on the performance of various remedial agencies with a view to presenting more authoritative inferences. An attempt is made herein to present the most pertinent information obtained.

The subcommittee wishes to express its thanks to all who cooperated in supplying data of any character.

A. Performance of Lines Protected by Ground Wires

1. General. The data received further confirm the value of ground wires in improving line reliability as formerly reported. Generally speaking, lines so protected show fewer outages per 100 mi. of circuit (and per 100 storms, where storm data were available) than unprotected lines. This is borne out by substantial reductions in outages on individual lines initially operated without, and later equipped with ground wires, on which comparative data for several seasons were submitted. Of course the number of interruptions varies widely with the territory in which the lines are located, and the frequency and severity of storms normal to the territory.

Interruptions on steel lines equipped with ground wire were consistently less (of the order of 20 to 50 per cent) than on lines not so equipped.

The data submitted for wood pole lines were less consistent, but in those cases where several years were reported a comparison of the average number of interruptions gave substantially similar results.

2. Effect of Ground Resistance. Data submitted by the Pennsylvania Water and Power Company throws some light on this subject. For three lines protected by ground wires, all operating at the same voltage but of somewhat different heights and with different average tower earth resistances, the following comparison has been set down for the year 1927:

Performance Comparison	During 1927		
Line designation	12.	56.	1516.
Circuit mileage	80.	80.	31.
Storms reported	44.	44.	19.
Breaker openings due thereto	11.	7.	5.
Breaker openings per 100 mi.	13.8	8.75	16.1
Breaker openings per 100 storms	25.0	15.9	26.3
Number of ground wires	1.	2.	1.
Approximate average percentage of shielding due to same	25.	40.	25.
Height of top conductor (approximate)	54.	58.	66.
Max. kv. induced voltage in top wire based on height and ground wire shielding at a gradient of 100 kv. per ft.	4000.	3500.	5000.
Average tower earth resistance—ohms	65*	55†	500 Est
Variation in same	10–277	10–277	

*Towers built on steel grillage.

†Towers built on concrete footings.

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*CONCLUDING REPORT OF THE 1927-1928 SUBCOMMITTEE OF THE POWER TRANSMISSION AND DISTRIBUTION COMMITTEE OF THE A. I. E. E.

H. L. Wallau, Chairman

H. H. Dewey, A. E. Silver, E. C. Stone,
C. L. Fortescue, P. Sporn, F. R. Weller.

1. A. I. E. E. Quarterly Trans., Vol. 47, October 1928, p. 1217.

Presented at the Winter Convention of the A. I. E. E., at New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

The storm data were not available for all of the three years reported, the interruptions due to lightning per 100 mi. of circuit being as follows for these three lines:

Line Designation	1925	1926	1927
12	13.8	8.75	13.8
56	30.	20.	8.75
1516	48.4	48.4	16.1

This company also submitted a print showing:

a. The individual earth resistance per tower for approximately 150 consecutive towers, of lines Nos. 12 and 56.

b. The average profile of lines Nos. 12 and 56.

c. The accumulated flashovers at each tower for 17 years on line No. 12 and for 13 years on line No. 56.

The following indications were derived therefrom:

1. Flashovers were relatively more numerous at points of higher elevation.
2. Flashovers were relatively more numerous at towers having the higher earth resistances. Towers having earth resistances below 50 ohms were in general less subject to flashovers, the percentages being 39 for line No. 12 and 24 for line No. 56 for the periods reported.
3. Line 12 (steel grillage 65, ohms resistance) averaged 4.6 flashovers per year, while line No. 56 (concrete footings 55 ohms resistance) averaged but three flashovers per year for the section of lines plotted on the print submitted.

Two other lines of the same nominal voltage operated by the above company in the same general territory but constructed without ground wires gave interruptions per 100 mi. of circuit as follows:

Line designation	1925	1926	1927
1112	82.6	121.5	32.6
1314	51.7	90.	50.

The average interruptions per 100 mi. of circuit for the three lines protected by ground wires were 23.1 as against 71.4 for the two lines not so protected.

3. Comparison of protection afforded by two ground wires as compared with a single ground wire. The following memorandum submitted by the Pennsylvania Water and Power Company indicates a betterment from the use of two ground wires, compared with one:

Insulator Flashover Record

"At the 19th Convention of the Pennsylvania Electric Association, a paper entitled 'A 15-Year Insulator Flashover Record' was presented. The purpose of this paper is to bring this record up to date by adding the information collected during 1926 and 1927.

"The conclusions drawn from the data presented in 1925 are as follows:

1. During a lightning surge, the top conductor of the circuit without ground wire is unquestionably raised to a higher potential than the lower one.
2. The maximum trouble from lightning on any one line can be expected at the highest elevation.
3. The more insulation on a line the freer it will be from lightning troubles.
4. A ground wire will reduce the induced surge voltage on the top conductor at least, and to that extent will be beneficial to the operation of the line.
5. Arcing horns at the bottom of an insulator string will reduce the lightning flashover voltage of the string.

"The addition of the 1926 and 1927 record seems to add further and more conclusive proofs to the conclusions already drawn."

Table II indicates that over a period of 10 years, line No. 12, equipped with one ground wire and no arcing horns, flashed over 111 times; line No. 56, paralleling No. 12 for its entire length (80 mi.) and equipped with arcing horns and two ground wires, flashed over 152 times in the same period.

TABLE NO. II

Line no.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	Total	Remarks
12	23	10	2	11	11	16	5	10	15	8	111	1 G. W.
56	17	16	8	16	16	19	5	32	16	7	152	2 G. W.

Data on other circuits indicate that the reduction in flashovers of the strings due to the horns would account for 53 of the 152 flashovers. Eliminating these, the estimated performance of line No. 56 is 99 flashovers versus 111 for line No. 12, a reduction of 11 per cent, attributed to the presence of the second ground wire.

Data submitted by the Georgia Power Company further confirm theory in regard to the greater shielding effect of two ground wires versus one.

Of two circuits on the same tower line, each 107 mi. long, one of which was protected by a ground wire its entire length, while the other had a ground wire over certain sections, aggregating 15 mi. in length, the circuit entirely protected had four outages in 1927 and the other, eight. In each case, three of these outages were accompanied by the burning in two of a line conductor. On the basis of the total interruptions, the first circuit was twice as reliable as the first. Omitting wires burned off (possibly as a result of direct strokes) the remaining interruptions were as one is to five.

Of nine wires burned off in 1927, three were on unprotected circuits, three on circuits with a ground wire over the opposite circuit, and three on circuits with a ground wire above them, but having only one ground wire on the tower. None was burned off on lines where

each of the two circuits was protected by an individual ground wire, although considerable mileage of this type was within the area in which the other lines were affected.

Considering all lines constructed with one or two ground wires as being protected, this company's records for 1927 for practically equal mileages of 110-kv. lines show interruptions of 93 per 100 storms for protected lines and 400 interruptions on the same basis for unprotected lines.

4. Earth Resistances. One company (Dayton Power and Light Company) reporting stated in a general way that marked improvement had resulted from the installation of a ground wire on 66-kv. wood pole lines and gave the following data in regard to it:

"These lines (54 mi.) operated until August 1925 (20 months) when the installation of the static wire was completed. The installation covered a period of about six weeks.

"The static wire consisted of 1-5/16 in. strand conductor attached to the end of a 4-ft. bayonet above the pole top, connected electrically to the bayonet and grounded at the base of each pole with a No. 4 copper wire stapled to the pole soldered into the end of a ¾-in. pipe, 6½ ft. long driven at the base of each pole. Every tenth ground rod was left disconnected from the static wire for test purposes. Tests made March 9 and May 8, 1928 show resistances as follows:

Pole—Ground pipe		Static wire	
March 9	May 8	March 9	May 8
92.5	70.	17.5	20.
147.5	110.	27.5	20.
43.	37.5	5.	7.5
24.5	22.5	5.5	7.5
30.5	25.	5.5	5.
35.	40.	10.	10.
23.	22.5	9.	7.5

"Prior to the completion of the static wire, 40 flashes were encountered, 99 insulator units being destroyed. After the completion of the static wire up to the present time (May 1928) 7 flashes were experienced with 21 units destroyed. Also prior to the completion of the static wire 5 poles and one crossarm were destroyed by lightning. None have been destroyed since."

5. Shattering of Wood Crossarms. Dallas, Texas, reports as follows for 60-kv. wood lines equipped with ground wire and similar lines not so equipped:

	With ground wire		Without ground wire	
	1926	1927	1926	1927
Circuit mileage.........	318.3	318.3	844.4	895.9
Arms shattered.........	0.	1.	39.	11.

A reduction in crossarm shattering was obtained in 1927 by grounding the hardware at each structure with a ground rod (but without installing an overhead ground wire) on 696.6 mi. of line.

For the 60-kv. lines reported the average interruptions per 100 mi. of circuit, for the years ending with 1927, were as follows:

Steel lines with one ground wire......	3.5
Wood lines with one ground wire......	6.3
Wood lines without ground wire......	2.5

B. Special Construction with a View to Reducing Lightning Outages

One company (Public Service of N. J.) reports, "There is a study being made on the use of wood construction for 26-kv. lines so as to take advantage of the inherent insulation in the wood poles. This study was initiated because it was found that the majority of flashovers were occurring at corner poles which were heavily guyed, and therefore, most of the insulation provided by the wood was short circuited. In connection with this problem, we are studying methods of insulating guy wires so that the insulation at the pole will be retained."

Another company (Cleveland) is at present building a short (5 mi.) 33-kv. wood line protected by insulated ground wire. Steel pins and crossarms are used and these are all bonded. The dry flashover of the ground wire insulators is (86 kv.) about half that of the line insulators (165 kv). The ground rods (every fourth pole) are carried down the pole on insulators to a point about ten feet from the ground. Insulators having a flashover of 125 kv. are cut in all guys at the pole.

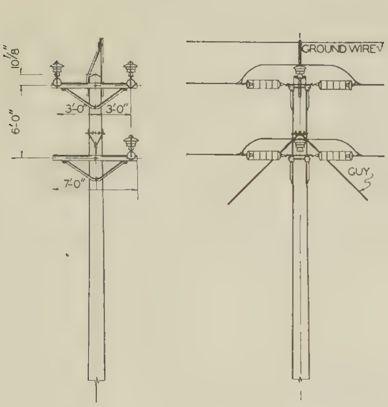
The Tampa Electric Company reported definite experience on three types of construction shown in the accompanying illustration.

In 1926, 83 mi. of circuit of Type *A* construction were operated at 66 kv. One hundred and twenty electrical storms were experienced resulting in 57 "kick-outs" or 47.4 per 100 storms.

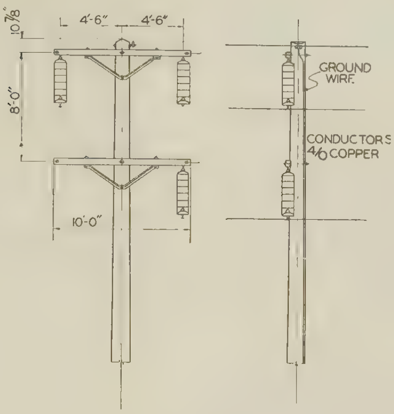
In 1927, 30 mi. of circuit of Type *A* construction were in operation, 30.3 mi. of Type *B* construction and 29.7 mi. of Type *C* construction. There were 121 electrical storms experienced on each with the following operating record:

Construction	Kick-outs	Insulator replacements
Type A	34	10
Type B	2	6
Type C	8	0

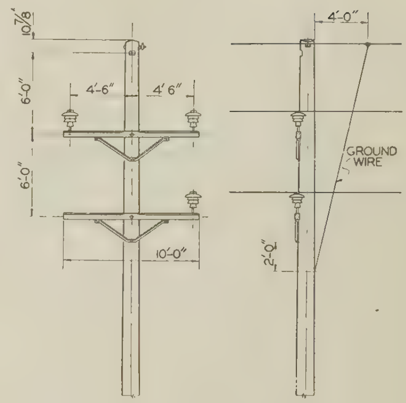
Mileage and storms being equal for each line, results are directly comparable. Construction *B* with seven suspension insulators and therefore a very much higher flashover value than construction *C* naturally gave the best results, but the improvement of construction *C* over *A* is very marked. Of course a single year's experience cannot be taken as conclusive. It should be noted that these circuits were among the very few reported which were operated with ungrounded transformer neutrals.



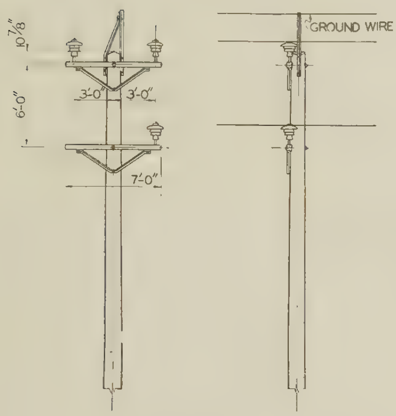
"A" Tangent



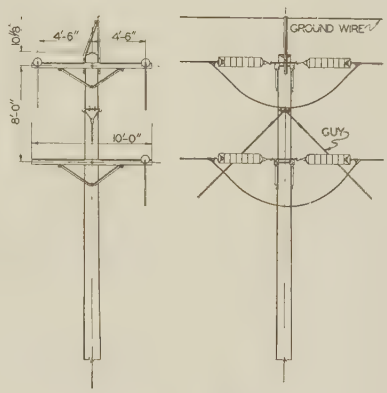
"B" Tangent



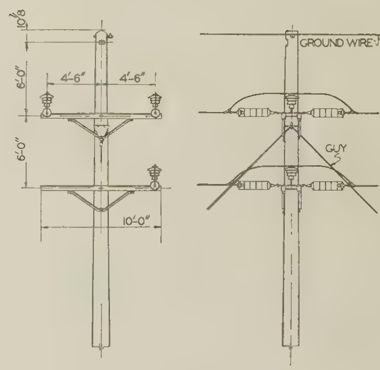
"C" Tangent



"A" Anchor



"B" Anchor



"C" Anchor

Three Types of Construction for 66-Kv. Wood Pole Line

These types are used by the Tampa Electric Company

C. Inferences

The following inferences may be drawn from the data submitted in connection with the preliminary report made to the committee and those subsequently received and partially presented herein:

1. Properly installed, an overhead ground wire materially increases line reliability by reducing flashovers due to lightning.

2. In general, points of higher elevation along transmission lines are more subject to flashovers than those of lower elevation.

3. Flashovers on lines equipped with ground wires are more likely to develop at structures where the value of the earth resistance is high, especially if materially above 50 ohms.

4. Earth resistances vary widely with the character of the soil, and, in the case of steel structures, with the nature of the foundation, making tests necessary if reasonable assurance as to their probable values is desired for any given installation.

5. In practise the installation of multiple ground wires on a transmission line appears to check theory, affording greater protection than a single wire.

6. Shattering of wood poles and crossarms is greatly reduced by properly installed overhead ground wires and also by bonding and grounding all hardware at every pole.

7. Special construction may be resorted to with expectancy of reduced lightning outages on wood pole lines.

8. The use of fused grading shields offers a promise of reduced outages due to flashovers, and materially improved operation should result when this type of protection has been perfected through the development of more reliable fuses and other details of construction.

The subcommittee takes this occasion to present the following recommendations:

1. The committee commends in general the use of overhead ground wires.

2. High-conductivity ground wires have advantages from the standpoint of carrying off the energy, especially of direct strokes. They are also of assistance in relaying and eliminating telephone inteference. Such high conductivity may be secured with the use of a steel core surrounded by a layer of either copper or aluminum or by the use of Copperweld steel conductor.

3. The installation of the ground wire should be as thorough, mechanically, as that consistent with the line conductors. It should be mounted with flexible supports.

4. Ground wires should be connected to each tower in a steel tower line and to ground at least every thousand feet on a wood tower line and an effort should be made to secure low-resistance grounds.

5. More data such as given in this report are desirable in order to substantiate the theory in regard to lightning effects and the use of overhead ground wires.

6. Due to the large number of variable factors which enter into the performance of transmission lines and the functioning of overhead ground wires during lightning disturbances, and the limited amount of available operating data which can be used in making comparisons, it is impossible to draw definite conclusions regarding the effectiveness of overhead ground wires for improving transmission line performance. Therefore it is urged that the companies which have been keeping accurate records of transmission-line performance continue this work, and other companies having transmission lines with and without overhead ground wires which are subject to comparable storm influence, and whose insulation strengths are uniform throughout their lengths and which are connected to the system by means of automatic switching equipment, prepare to keep records on these lines including storm data, insulator replacements, damage to structures, etc. Data on transmission line operation submitted to the Institute should include all influencing factors in the design, construction, and operation of the lines on their performance. Accumulation of data for a number of years is necessary in order to average out as many variables as possible.

7. From the rather limited amount of data obtained comparing performance of lines with and without overhead ground wires it would seem that a marked reduction in the number of flashovers due to lightning should be experienced on lines equipped with properly installed overhead ground wires. The influence of methods employed in grounding and ground resistance, conductivity of the ovehead ground wires, spacings, etc., also the effectiveness of overhead ground wires in protecting lines from direct lightning strokes, will require considerable additional study.

8. For uniformity, the following record is suggested for each important transmission line. An earnest attempt should be made to keep the data accurate:

A. Physical Data.

1. Individual circuit mileage.
2. Height and arrangement of conductors.
3. Height and arrangement of ground wires, if any.
4. Kind of transmission structures and material.
5. Number and type of insulators in standard suspension string.
6. Effective 60-cycle flashover of same.
7. Data on arcing horns, grading rings, etc., if any.

B. Operating Data.

1. Number of electrical storms to which lines were exposed during lightning season or calendar year.
2. Number of flashovers resulting therefrom (per circuit, when more than one circuit is installed on the same line).
3. Number of insulators damaged by flashover and position of same.

Positions should include as far as possible:

a. Tower location,
b. Conductor position,
c. Position of unit in the string.

4. Any pertinent facts which may be uncovered in the investigation of a case of lightning damage.

The accumulated data should be forwarded early in February of each year to the Chairman of the Power Transmission and Distribution Committee so that the material may be studied and reported upon in the Committee's Annual Report.

SIMPLIFIED PRACTISE IN 1929

That simplified practise will be applied on an increasing scale by industry and business in 1929 is forecast by the increasing number of requests to the division of simplified practise for its cooperation; by the increasing number of inquiries reaching it regarding the application of simplified practise to wholesaling and retailing; and by the increased recognition and support accorded completed simplification.

Many of the inquiries reflect a good understanding of simplified practise, a familiarity with its adoption and use in manufacturing, and a desire to test its value in the solution of distributor's problems. There also appears to be a growing recognition among buyers in general, and purchasing agents in particular, that it pays to specify simplified lines when buying. Likewise, among jobbers and wholesalers, and to a lesser degree among retailers, there is trend not only toward stocking lines already simplified, but also toward individual simplification, wherein the distributor is analyzing his turnovers, line by line, and condensing his stocks to those items in most common demand.

Economies and benefits derived by those participating in the 100 simplifications effected with the aid of the division are becoming well known, and industries burdened with excessive variety, slow turnover, and increasing costs of stock maintenance are looking into simplification as a means of relief.

The high percentage of adherence to, or conformity with, the existing simplifications; and the fact that the division has 60 others under way, 20 of which came to it within the past few months, also indicate that simplification will be found among the better management plans of a good many firms in 1929.—*Technical News Bulletin.*

Abridgment of

Carrier-Current and Supervisory Control on Alabama Power Company System

BY W. I. WOODCOCK[1] and E. W. ROBINSON[1]

Non-member Non-member

Synopsis.—The experience of the Alabama Power Company with carrier-current telephony over power lines and supervisory control is outlined in the paper. A sketch is included of the early development of these systems, and this is followed by descriptions of the systems later installed throughout the Company's territory.

In an Appendix extracts are given from the general specifications for the equipment employed in the systems.

* * * * *

Early Carrier-Current and Supervisory Control Developments

No article on the subject of carrier-current and supervisory control on the Alabama Power Company's system would be complete without a brief résumé of early developments along these lines prior to the inception of the major program, which may be said to date from about 1925.

Prior to that time, the company had built up a communication system consisting of about 1400 mi. of telephone line, part of which consisted of separate pole lines on the same rights-of-way with the 110-kv. power lines, most of the remainder being carried on the same poles with 44-kv. and 22-kv. lines.

Due to the long parallels and comparatively small separation, these telephone lines were usually quite noisy, noise levels often being as high as 500 to 600 noise units. These conditions obtained in spite of the application of standard methods employed by the communication companies to eliminate such conditions. To cope with these troubles, considerable experimenting had been done with the use of high-power telephone equipment, such as "Wonderphones," but such equipment only partially overcame the difficulties.

The first development that seemed partially to fulfil this requirement was space radio, so that as soon as this reached a reasonable degree of development, the power company was ready to try it, and in 1922 installed Station WSY at Birmingham, with 250 watts capacity. This station had a very unusual record in the way of long distance transmission, but during the sleet and snow storms of 1922 and 1923, when practically all the communication lines were put out of commission, it was practically worthless for reaching the near-by generatng plants, although dispatching orders broadcast at that time were picked up as far away as Central America. Consequently, it was very soon perceived that space radio was not the answer, and in 1925 Station WSY was discontinued.

When carrier-current equipment reached a reasonable degree of development, the power company became interested in this, and in 1924 installed two 250-watt single-frequency simplex sets at stations about 60 mi. apart. It was soon found that simplex operation was very unsatisfactory. Furthermore, many troubles in operation were encountered, so that these sets were discontinued in 1925.

The experience with the first two sets when they were working properly, however, gave some insight as to the possibilities of satisfactory carrier-current equipment, and the power company therefore participated in a further trial installation in 1925. Two duplex, double-frequency, low-power sets were installed at substations about 65 mi. apart. This installation was extremely successful, although it had its shortcomings and convinced the power company engineers that carrier current was due for very serious consideration in the future expansion of the communication system.

The foregoing review of the communication situation up to 1925 will serve as an introduction for the later discussions of carrier-current equipment on the Alabama Power Company's system; a similar review of supervisory-control developments is in order. Early, the power company had realized the need for some form of supervisory control. It was realized that if a satisfactory system could be developed, service could be greatly improved and operating expenses reduced. Therefore, some time prior to 1925 experiments were started with a supervisory control system operating over a telephone circuit and employing d-c. impulses as a means of control.

The first application was not very successful, however, just as in the case of the carrier-current equipment this early installation served to visualize the enormously useful possibilities of such a control system.

1925 Expansion Program

Early in 1925 the Power Company was confronted with a very extensive program of expansion, which involved some major items of communication and supervisory control. In North Alabama there was an acute need for additional communication between Magella Substation (Birmingham), Huntsville, Sheffield, and Gorgas Steam Plant.

1. Both of the Alabama Power Company.

Presented at the Regional Meeting of District No. 4, of the A. I. E. E., Atlanta, Ga., Oct. 29-31, 1928. Complete copies upon request.

In Southwest Alabama two very long lines were projected, radiating from Lock 18 (Jordan Dam). One of these was to extend through Selma, Demopolis, Meridian, and Laurel, to Hattiesburg, with two possible branches beyond that point. The over-all length was to be about 325 mi. A second line, the route of which was not so definitely decided, was to extend from Lock 18 to Flomaton, with branches to Pensacola and Mobile. The total length of this line was to be in

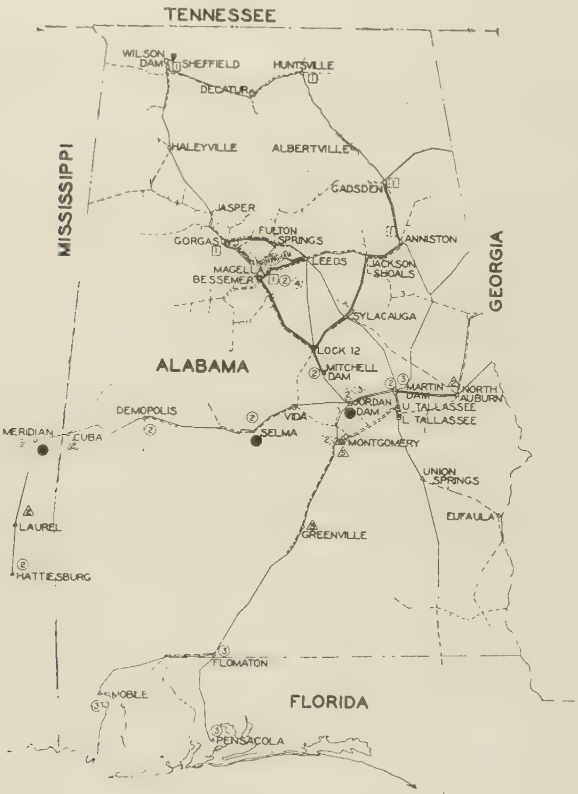


Fig. 1—Electric Distribution Lines in Alabama and Portion of Florida and Mississippi

excess of 300 mi. Because of the distances involved and necessity for keeping the cost low, it was planned to use carrier current for primary communication, backed up by a secondary system of communication making use of two insulated overhead ground wires which formed a part of the typical construction proposed for these lines.

The first parts of this program to come up for active consideration were the North Alabama Loop and a portion of the Mississippi line extending from Lock 18 to Demopolis.

North Alabama Carrier-Current Project

Stations under consideration were located roughly at the points of a quadrilateral as indicated in Fig. 1 (Index 1). Maximum distances involved were approximately 150 mi. with parallel circuits between all locations. Communication was required from chief dispatching point to all other stations for operation, and in addition, inter-office communication for commercial purposes was essential and necessitated wire line varying in length from 1½ to 4 mi. Carrier equipment was to be coupled to 110-kv. lines, forming a loop, constituted of a single circuit in certain sections and parallel circuits in others, and including a 44-kv. parallel for approximately 65 mi. (Magella to Anniston) on one branch, and approximately 50 mi. (Magella to Jasper) on the other branch of the loop circuit.

Apparatus decided upon and purchased was of the double-frequency duplex type, having a nominal low power rating of one watt intended for regular operation, and high-power rating of 50 watts for use under abnormal line conditions or severe atmospheric disturbances. Antenna coupling was decided upon due to trouble previously experienced with early types of coupling condensers, and due to cheaper construction possible with antennas without sacrifice of efficiency, (as indicated from test installations).

Operating Results. The first two stations installed were at Magella and Sheffield, approximately 120 mi. apart, and operated satisfactorily on low power from station to station under normal line conditions. High-power range appeared adequate to meet routine switching conditions and operating set-ups. When an intermediate set was installed (Gorgas), trouble began to appear on terminal equipments due to difficulty in making adjustments to accomodate high-energy levels from near-by set to avoid howling, and yet be sufficiently sensitive to hear distant station. Installation of the fourth set further complicated the operating problem by increasing maximum distance to 155 mi. and requiring more sensitive adjustments on terminal equipments. Received energy levels varied widely with switching on 110-kv. lines, and were so low as to make adjustments of relay's extremely difficult over the range of line conditions encountered.

When equipment was first installed, lines normally operated with loop circuit closed. Later it was found necessary to split the circuit at Sheffield. This change produced a marked reduction in received energy between terminal stations and required relay adjustments too close for reliability.

Interference. A few months after equipment on the North Alabama loop had been put into service, more powerful equipment was installed in Southwest Alabama. Immediately troubles due to interference were encountered. Even though frequency separation of equipments was more than 20 kilocycles, it was found that when one of the more powerful sets was in use all equipment on the North Alabama loop was held inoperative.

Experience with this equipment has shown the necessity of using more power when tying into a complicated power network as compared to commercial practise over straight-away lines. Means must be provided for using as narrow a frequency band as possible,—not over 5 to 8 kilocycles maximum,—because of necessity of multiple channels, and this band should tune rather sharply to minimize interference.

Southwest Alabama Carrier-Current Project—(Mississippi Line)

The Mississippi line channel, as finally decided upon, contemplated communication over a maximum distance of approximately 325 mi., as indicated in Fig. 1 (Index 2). Installation of ten sets was decided upon, seven were required to talk to all other sets of equal capacity, and three were of lower capacity, from which communication was required only to adjacent large sets.

Antenna coupling was decided upon, except for one location (Martin Dam), where physical location of lines and bus structures would have made necessary a double antenna and expensive construction due to an extremely long span over a river.

Apparatus purchased and installed is of the double frequency duplex type, having a 250-watt rating for large sets and a 20-watt rating for intermediate sets.

Distances between sets average, roughly, 50 mi., and equipment is in all cases installed in substations, several of which are non-attended.

Interphase coupling is used at all locations for transmitter, while at some locations the receiver is coupled phase-to-ground, using a third wire for receiving antenna. At other locations, phase-to-phase coupling is used to obtain combined transmission and reception on a phase-to-phase basis.

Operating Experience. Operating experience has shown the necessity of routine inspection and maintenance by a trained personnel at regular intervals. A special daily operating report form has been adopted which gives a record of performance and indicates units such as tubes or batteries that are nearing the end of their useful life. These report forms are forwarded to carrier-current maintenance men, and failing units are checked and replaced, if necessary, on the next regular routine inspection. Field forces keep the batteries filled, replace burned out tubes, and keep the equipment clean, but have definite instructions not to change any adjustments or make any modifications or additions either to carrier-current equipment or line extensions. Operating results have, in general, been quite satisfactory, and an over-all efficiency of 93.7 per cent has been obtained on 250-watt sets. Complete records are not available on intermediate 20-watt sets, but operating results have not been as good, probably due in large measure to a less completely worked out design.

Prior to the use of carrier current over power conductors, communication facilities of power companies were entirely separate and additions to or modifications of power lines were made without affecting the communication system. Installations of carrier-current equipment have entirely changed this condition, and complete information on changes in operating procedure, as well as line modifications or additions, must be transmitted to the communication engineers if maximum results are to be obtained. A short tap line may constitute a low impedance shunt, or a transformer bank installation may effectively open circuit a line, at carrier-current operating frequencies, and remedial measures must be taken if carrier current equipment is to remain operative.

Southwest Alabama Carrier-Current Project—(Mobile Line)

Stations on the Mobile channel, as indicated in Fig. 1 (index 3) are, with one exception, fed by a single-circuit 110-kv. line. Typical construction of this 110-kv. circuit is the same as used on the Mississippi line, except that insulated overhead wires on the entire line are composite steel-aluminum cables. Coupling is direct to the insulated overhead wires by means of 0.001 microfarad condensers having a 15,000-volt rating.

Southwest Alabama Supervisory Control Project

Supervisory control is usually considered to be extra remote electrical control, generally employing the ordinary dial and selector mechanisms of the automatic telephone, with some sort of electrical control circuit connecting the sending (dial) and receiving (selector) stations. There is also usually some form of answer-back signal to indicate the functioning of the controlled equipment. In discussing supervisory control on the Alabama Power system, the Mississippi line was taken as the best example, since it is typical, and is the oldest and most complete of the supervisory control installations.

The Mississippi line is a 110-kv., single-circuit line. The supporting structures are creosoted pine H-frames. The power conductors are spaced 14 ft. apart horizontally, and, about 9 ft. above and between them, there are two ½-in. Siemans-Martin steel ground wires, carried on the projecting tops of the poles. There are insulated by 20-kv. pin type insulators or suitable strain insulators. The insulated overhead ground wires are transposed at intervals of approximately 4 mi. At the various substations they are carried in to the supervisory control and emergency telephone equipment through appropriate protective devices. At 2-mi. intervals drops extend down the poles, on 20-kv. insulators, from the insulated overhead ground wires and are terminated at suitable protective equipment so that patrolmen may use the insulated overhead ground wires as a communication circuit in emergencies. At approximately 15-mi. intervals, and at the sub-

stations, there are motor operated, supervisory controlled, air break sectionalizing switches. Also, at some of the substations,—Selma, Demopolis, and Cuba,—there are certain supervisory controlled oil circuit breakers.

Fig. 2 shows the various supervised switches on the Mississippi line.

The installation uses of the insulated overhead ground wires to carry alternating-current impulses of medium frequency (450 to 600 cycles) which operate the supervisory controlled equipment. These impulses are put on and taken off the insulated overhead ground wires at substations and sectionalizing switches by means of special insulating and drainage transformers. The

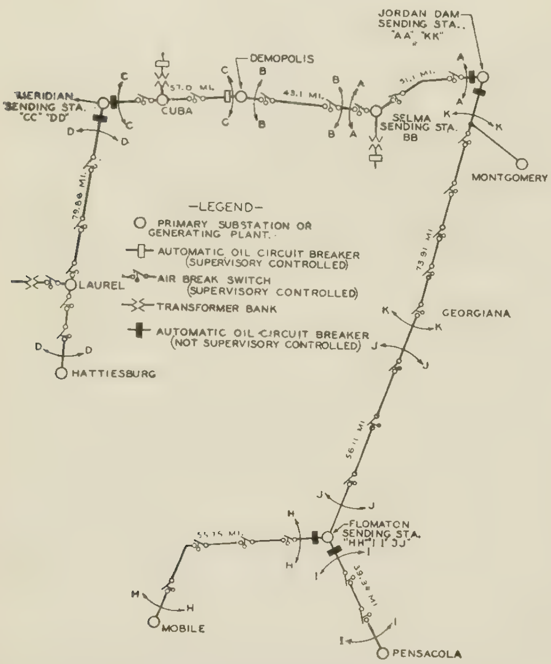


Fig. 2—Diagram of Supervisory Control on Alabama Power Company Lines

middle points of the high-tension windings are grounded, providing ground connections for the insulated overhead ground wires. These transformers were so designed and protected as to provide low impedance paths to ground for high-frequencies from either ground wire, to insert comparatively high impedance between ground wires for frequencies of 600 cycles and less; they were to provide ample insulation between the ground wires and the supervisory control and emergency telephone equipment, and, finally, they were not to interfere with the use of the insulated overhead ground wires for audio communication. As to functioning, it was proposed that the operator at any control station might ascertain the position of any supervised switch or breaker in his control section. If open, he might close it, and if closed, he might open it. In the two latter cases, he was to get an indication of correct and complete operation. Various safeguards are provided, the most interesting being the use of 450 cycles to set up the relays ready for operation, and 600 cycles actually to perform any operation. Actual operation of the switches is by means of motor mechanisms driven by the local 12-volt or 110-volt storage batteries.

All equipment is inspected and tested on a monthly schedule, and so far the operation and maintenance cost has been comparatively low, being practically confined to the time and expenses of the inspector.

For the period from July 1927 to July 1928, all supervised equipment in the 90-mi. section from Hattiesburg to Meridian was given a monthly operating test with the power line energized, up to and including the motor mechanisms. In this period there was only one failure to function properly, and this was due to improper adjustments at one sectionalizing switch following installation of a new type insulating and drainage transformer which was being tried.

The inspection and testing of all carrier current and supervisory control equipment for the Jordan Dam-Hattiesburg line takes less than half the time of two men.

Insulation of the overhead ground wires and their use for supervisory control and communication does not appear to have materially lessened their protective value, as line troubles have been very few and not of such nature as to be attributable to decreased protective value of the overhead ground wires. Momentary interruptions, in spite of very bad lightning conditions, have been comparatively few, varying from a minimum of 0 to a maximum of 6 per month for the entire line.

The operation and maintenance of the supervisory control equipment is not extremely difficult, nor beyond the capacity of a first-class operator or maintenance man.

Conclusions

In view of experience on the Alabama Power Company system, the following conclusions as to carrier current communication may be drawn:

It is thoroughly practicable for power lines, but operates better on radial lines than networks. Short taps on lines used as carrier-current channels must be avoided or isolated.

For long distance, it is more reliable and economical than telephone lines.

Careful study of power circuit characteristics prior to installation of carrier current is essential.

Careful, frequent, and competent inspection and reporting are essential to satisfactory operation.

There are certain improvements and modifications in equipment that should be made, notably—redesign for cheaper and easier installation; greater accessibility for inspections and repairs; greater factors of safety and wider operating margins; improved battery charging equipment and elimination of "B" and bias batteries if possible.

Abridgment of

Flux Linkages and Electromagnetic Induction in Closed Circuits

BY L. V. BEWLEY[1]

Associate, A. I. E. E.

Synopsis.—It is shown that the flux linkages of a circuit may be changed in two very different ways—either the flux may be varied causing a voltage to be induced according to Faraday's Law of Electromagnetic Induction, or the turns may be varied by a substitution of circuit without inducing a voltage. In the Appendix, it is mathematically shown that the flux may be changed either by transformer or cutting action, but that the presence of one or the other of these actions is dependent on the choice of reference axes. Thus, any argument to the effect that one of them in particular is a necessary part of all induction phenomena is futile. It is possible to identify in every d-c. machine the building up of flux linkages so as to generate a voltage, and the reduction of flux linkages by a substitution of circuit so as not to generate a voltage. The alternate working of these two methods for changing the flux linkages of a circuit is an essential and necessary feature of every d-c. dynamo-electric machine. General criteria are introduced for ascertaining in any given case the nature of the changes in interlinkages which occur, and whether voltages are induced thereby. By way of application, a new restriction on the use of coefficients of inductance is pointed out, the sliding contact and homopolar machine are discussed, and finally a table has been prepared illustrating the various types of flux linkages found in familiar apparatus.

INTERLINKAGES

THE purpose of this paper is to examine the various changes in flux linkages that occur in electrical circuits, and to classify them with respect to the type of voltage generated. With this end in view a general equation is derived for calculating the voltage induced in a circuit of any shape moving or changing its configuration in a variable field of magnetic flux. Therefrom criteria are developed and their application demonstrated for determining in any given case the nature of the changes in interlinkages that take place and whether voltages are induced thereby.

In order that no ambiguity shall exist as to the meaning of the term *circuit*, as used in this paper, the following definition shall apply—

Any closed contour in space, whether in conducting media or not, and regardless if parts thereof are common to any other selected contours, constitutes a closed circuit.

In most cases of engineering practise, what constitutes a *turn* is usually so obviously self evident as to require no explanation. But when tubes of induction are interwound with a circuit, there may be some chance for confusion. The following arbitrary definition will therefore apply from the point of view of this paper.

If by means of imaginary lines it is possible to subdivide a circuit into a network of N cells such that each cell encloses the same flux ϕ and in the same direction, then the circuit is said to have N turns with respect to ϕ.

On the basis of the above definition, the actual physical loops may be made by either the circuit or by the tubes of induction, and the specification of the number of turns present is entirely arbitrary. In any particular case, the induced voltage may be computed on the basis of N circuits in series each linked with a flux ϕ, or of a single-turn circuit linked with a flux $N\,\phi$. To prove the equivalence it is only necessary to note that the voltage round any circuit C, which has been so subdivided into N cells 1, 2, 3 . . . N, is equal to the sum of the voltages round each cell, all taken in the same direction, thus

$$E_c = E_1 + E_2 + \ldots + E_N$$

If a circuit consists of n concentrated turns linked with a flux ϕ, then the interlinkages are

$$\Omega = n\,\phi \tag{1}$$

and their rate of change is

$$\frac{d\,\Omega}{d\,t} = n\frac{d\,\phi}{d\,t} + \phi\frac{d\,n}{d\,t} \tag{2}$$

The term $n\,d\,\phi/d\,t$ of Equation (2) accounts for those changes in interlinkages which are caused by varying the flux through the circuit. It expresses the Law of Electromagnetic Induction deduced experimentally by Faraday and stated as follows:

"Whenever the total flux through a circuit varies, there is an electromotive force induced whose magnitude is proportional to the rate of diminution of the total number of tubes of induction threading the circuit."

The law is universally true and applies when either or both the magnetic system and circuit are moving. While $n\,d\,\phi/d\,t$ is the general and most concise expression of the law of induction, it is nevertheless convenient to expand it into a more useful form in order to facilitate an understanding of its meaning and application. It is perhaps intuitively evident that the total flux threading a circuit may be changed either by varying the density of those tubes of induction already linked with the circuit, or by moving the circuit through the field. However, it is shown mathematically in Appendix I, by means of the calculus of variations and vector analysis, that $n\,d\,\phi/d\,t$ is composed of these two natural components. Two less

1. General Transformer Engineering Dept., General Electric Co., Pittsfield, Mass.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

general proofs are also included which are not dependent on the processes of mathematical physics, but whose solutions exhibit the same form as that of the general case, and from which the latter may be easily inferred. The expanded form of the law of induction developed in Appendix I is

$$e = -N\frac{d\,\phi}{d\,t} = -\sum N\left(\frac{\partial\,\phi}{\partial\,t} + \int_c \mathbf{B}\,.\,\mathbf{V}\times d\,\mathbf{s}\right)$$

$$= -\sum N\left\{\frac{\partial\,\phi}{\partial\,t} + \int_c \left|\begin{matrix}\alpha & \beta & \gamma\\ u & v & w\\ dx & dy & dz\end{matrix}\right|\right\}$$

$$= -\sum N\left(\frac{\partial\,\phi}{\partial\,t} + \int_c B_n\,V\sin\theta\,ds\right) \qquad (\mathbf{16})$$

where the summation is to range over all of the circuits of concentrated turns which are connected in series.

The definitions of the symbols are given in the Appendix and in the attached list of symbols.

The first term of $d\,\phi/d\,t$ depends on the position and configuration of the circuit relative to the reference axes, and on the rate of change of the magnetic field. It is independent of the rate of motion or change in configuration of the circuit and is therefore called the "variational component," or referred to as "transformer" action.

The second or "motional" term of these expressions depends upon the velocity of the elements of the circuit and upon the instantaneous value of the components of

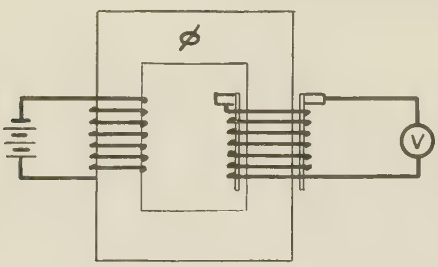


FIG. 1—CHANGING THE FLUX LINKAGES BY UNWINDING TURNS AND WITHOUT INDUCING A VOLTAGE

flux density at the elements and normal to their planes of motion. It represents the "cutting" action of the moving circuit.

Thus the two terms of the general e. m. f. equation have a real physical significance; but they are not invariant to a change of coordinate axes. In some apparatus,—as for example—in the case of the transformer,—there is only one possible choice of axes. But in other instances, either or both terms may be present, depending on the choice of reference axes. Thus, in the polyphase induction motor, the voltage induced in the rotor is of the type $(\partial\,\phi/\partial\,t + B\,l\,v)$ or $\partial\,\phi/\partial\,t$ or $B\,l\,v$; corresponding respectively to axes taken on the frame, on the rotor, or rotating with the stator m. m. f.

The term $\phi\,d\,n/d\,t$ of Equation (**2**) accounts for those changes in interlinkages which are caused by varying the number of turns linked with a given rigid distribution of flux. It may appear that there are two possible interpretations to the meaning of $\phi\,d\,n/d\,t$. First, the turns may be changed without cutting the flux, as by winding them around it as indicated in Fig. 1, where the turns are wound onto a drum which revolves about a magnetic core. The electric circuit is completed through a slip-ring and brush. In such an arrangement, the turns n are constant until the connection to the slip ring passes under the brush, when the number of turns change abruptly to $(n \pm 1)$. Thus $d\,n/d\,t$ is infinite at that instant, but otherwise is zero. *No voltage is induced by this process.* A unique d-c. generator based on this process is described in the paper. A variation of the same scheme is in fact employed in every d-c.

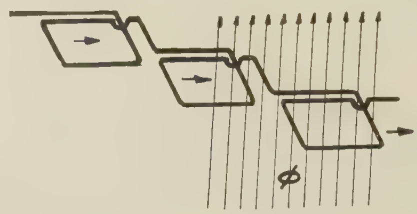


FIG. 2—PILING UP OF TURNS

generator, and will be hereafter referred to as a *substitution of circuit.*

The second interpretation of $\phi\,d\,n/d\,t$ might seem to be the piling up of turns by cutting through the flux, as illustrated in Fig. 2. For such a point of view it is necessary to define a full turn as one linking all of the specified amount of flux, and a partial or fractional turn as one linking only a part thereof. But such a definition is contrary to the idea of a turn as something necessarily integer, and leads to endless confusion and uncertainty in practise. In fact, if Equation (**1**) is defined on the basis of concentrated integer turns, then $\phi\,d\,n/d\,t$ cannot possibly admit of this second interpretation; for the several turns which make up the circuit of Fig. 2 are not concentrated, that is, they do not all link the same flux at the same instant. Under the conditions of such a definition each of the several turns must be regarded as separate circuits connected in series, and the changing flux linkages due to the motion of the coil are then fully accounted for by $n\,d\,\phi/d\,t$. It is therefore evident that any attempt to account for the change in interlinkages due to the motion of the circuit through the flux, by any term other than $n\,d\,\phi/d\,t$ would be superfluous and lead to a duplication of result, or else place an unnatural restriction on the definition of $n\,d\,\phi/d\,t$.

Thus it is seen that the interlinkages of a circuit may be changed in two very different ways:

(1) The flux threading a circuit may be changed either by "transformer" or "cutting" action causing a voltage to be induced according to Faraday's Law of Electromagnetic Induction.

(2) The turns linking the flux may be changed in

such a way as not to cut through the flux, as by winding on turns or substitution of circuits, thus effecting a change of interlinkages *without* inducing a voltage.

The first of these two methods makes possible the generation of a voltage by electromagnetic induction. The second offers the only possible way for obtaining an average or d-c. component therefrom by means of a dynamo-electric machine.

THE AVERAGE OR D-C. COMPONENT OF VOLTAGE

The average voltage induced in a non-interrupted circuit over the time interval $(t_2 - t_1)$ is

$$e_{av} = -\frac{n}{t_2 - t_1}\int_{t_1}^{t_2}\frac{d\,\phi}{d\,t}\,d\,t = -\frac{n}{t_2 - t_1}\,(\phi_2 - \phi_1) \qquad (3)$$

It is evident that $e_{av} \rightarrow 0$ if averaged over a sufficiently long period of time, for the flux ϕ_2 cannot perpetually increase.

Suppose, however, that at time t_2 when the flux included by the circuit is ϕ_2, the interlinkages be reduced to some lower value ϕ_1 by effecting a substitution of circuit, $\phi\,d\,n/d\,t$; and then that the flux linkages of the new or substituted circuit be increased by increasing the flux. Any number of such cycles may be passed through in succession and the average voltage induced over all of the cycles is

$$e_{av} = -\frac{\Sigma\,n\,(\phi_2 - \beta_1)}{\Sigma\,(t_2 - t_1)} \qquad (4)$$

If every substituted circuit and cycle is alike this reduces to

$$e_{av} = -\frac{\phi_2 - \phi_1}{t_2 - t_1}\,n \qquad (5)$$

Thus a d-c. component of voltage may be obtained over any period of time, merely by providing some arrangement whereby new circuits may be continually substituted as the limit in flux linkage is reached for each. And therefore in any d-c. generator the voltage must be induced by a change of interlinkages $n\,d\,\phi/d\,t$; but the interlinkages must be held within finite bounds by a periodic reduction $\phi\,d\,n/d\,t$.

The most familiar arrangement of this kind is the ordinary d-c. generator, wherein a commutator functions as an automatic switch connecting the armature coils to the external circuit. At regular intervals each armature coil is disconnected from the external circuit on being short circuited by the brushes, and is then substituted back into the circuit, but with reversed connections.

THE GENERAL CRITERIA

In the light of the foregoing developments, the following criteria are introduced as a means towards systematically determining the nature of the interlinkages which occur in electrical apparatus, and whether voltages are induced thereby. It is not supposed that these criteria will reduce the analysis to a simple mechanical process, but they are a step in that direction. The proposed rules are:

(a) Choose a set of coordinate axes as convenient and refer all changes in flux or in position and configuration of the electric circuit to these axes. (Transformation of coordinates, if properly done, is always permissible).

(b) If that flux linked with the electric circuit at any instant, (*i.e.*, with the circuit fixed,) is a function of time with respect to the coordinate axes, it will induce in the circuit a voltage

$$e_1 = -\,\Sigma\,n\,\partial\,\phi/\partial\,t$$

where the summation is to include all those groups of concentrated turns of which the total circuit is composed, and ϕ is the flux linked with any group of n concentrated turns. By "concentrated turns" is understood all those turns connected in series which link exactly the same flux, although they may be physically widely distributed and at different places in space.

(c) If any of the elements ds of an electric circuit are moving with respect to the coordinate axes so as to "cut" the flux of the magnetic circuit, they will induce a voltage

$$e = -\,\Sigma\,n\,\int_c B_n\,V\sin\theta\,ds$$

where

V = velocity of the element ds

θ = angle between the direction of v and ds

B_n = component of flux density normal to the plane of V and ds

$\int_c$ = the integral for all the elements ds taken completely round the circuit.

(d) Any change of interlinkages which cannot be classified under either (b) or (c) is due to a substitution of circuit, $d\,n/d\,t$, and will necessarily involve some switching operation, sliding contact, or transfer of turns. No voltage will be induced thereby, except in so far as the flux itself is changed; either because the exciting m. m. f. is furnished by the turns themselves, or because they happen to be made of a magnetic material whose shifting changes the reluctance of the magnetic circuit.

(e) It is impossible to induce a d-c. voltage in an uninterrupted circuit. However, a d-c. voltage may be obtained by repeatedly building up the flux linkage by methods (b) and (c) and reducing them by method (d). In this way unidirectional voltages are induced during the increase of flux linkages, but no voltages are induced during their reduction.

APPLICATIONS

A few examples are discussed under this section of the paper to fix in mind the principles involved, and the method of applying the general criteria. It is pointed out that there is a distinct restriction on the use of coefficients of inductance quite apart from saturation effects. The sliding contact and homopolar generator are briefly described and analyzed. Finally, a table

has been compiled indicating the nature of the interlinkages which occur in some of the more familiar types of electric apparatus.

Conclusions

The phenomena of changing flux linkages and electromagnetic induction in electrical circuits may be classified according to the following scheme:

Thus the flux linkages of a circuit may be changed by changing either the flux or the turns. The flux may be varied either by transformer action or by cutting action. (These are also known respectively as the

TABLE I
TYPES OF INTERLINKAGE PHENOMENA

Apparatus	Reference axes	Circuit considered	Change of interlinkages: Increase	Change of interlinkages: Decrease	Voltage generated
Transformer	On core	Either	$n \frac{\partial \phi}{\partial t}$	$n \frac{\partial \phi}{\partial t}$	a-c.
Syn. generator	On field	Armature	$n\,Blv$	$n\,Blv$	a-c.
	On armature	Armature	$n \frac{\partial \phi}{\partial t}$	$n \frac{\partial \phi}{\partial t}$	a-c.
Polyphase ind. motor	On stator	Rotor	$n\left(\frac{\partial \phi}{\partial t} + Blv\right)$	$n\left(\frac{\partial \phi}{\partial t} + Blv\right)$	a-c.
	On rotor	Rotor	$n \frac{\partial \phi}{\partial t}$	$n \frac{\partial \phi}{\partial t}$	a-c.
	Rotating synchronously	Rotor	$n\,Blv$	$n\,Blv$	a-c.
D-c. generator	On field	At brushes	$n\,Blv$	$\phi \frac{d n}{d t}$	d-c.
	On armature	At brushes	$n \frac{\partial \phi}{\partial t}$	$\phi \frac{d n}{d t}$	d-c.
Unipolar generator	On core	At brushes	$n\,Blv$	$\phi \frac{d n}{d t}$	d-c.
Generator in Fig. 3	On core	At brushes	$n \frac{\partial \phi}{\partial t}$	$\phi \frac{d n}{d t}$	d-c.
Sliding contact	On core	At contacts	$\phi \frac{d n}{d t}$	$\phi \frac{d n}{d t}$	None

RATE OF CHANGE OF FLUX LINKAGES

$$\frac{d\,(n\,\phi)}{d\,t}$$

FARADAY'S LAW OF INDUCTION

$$n \frac{d \phi}{d t}$$

(Depending on reference axes)

Transformer action
(or variational e. m. f.)

$$n \frac{\partial \phi}{\partial t}$$

A-C. VOLTAGE

Cutting action
(or motional e.m.f.)

$$n \int_c B_n\, V \sin \theta\, ds$$

A-C VOLTAGE

SUBSTITUTION OF CIRCUIT

$$\phi \frac{d n}{d t}$$

1. Sliding contact
2. Commutation or switching operation
3. Transfer of Turns

NO VOLTAGE

D-C. VOLTAGE

variational and *motional* components of e. m. f.) But whichever action is involved is dependent on the arbitrary choice of the references axes. Regardless of the way in which the flux through a non-interrupted circuit is changed, it will induce a voltage according to Faraday's Law. And if the period of time is taken sufficiently long, this e. m. f. must be alternating, or zero, for the flux cannot perpetually increase.

But the flux linkages may also be changed by varying the number of turns linked. If this is done in such a way as not to change the flux itself, it is classified as a *substitution of circuit,* and includes the sliding contact, transfer of turns, and commutation or switching operations. *No voltage can be induced by a substitution of circuit.*

The generation of an average or d-c. component of voltage depends on the alternate use of $n\,d\,\phi/d\,t$ and $\phi\,d\,n/d\,t$; that is, the flux linkages must be increased by increasing the flux and causing a voltage to be induced according to Farraday's Law. But these linkages must be held within finite limits by a periodic reduction with a substitution of circuit.

DECIBEL—THE NAME FOR THE TRANSMISSION UNIT

By W. H. Martin

In 1923 the "mile of standard cable" was replaced in the Bell System by a new unit for expressing telephone transmission efficiencies and levels. At that time, the generic term "transmission unit" was taken to designate this new unit, since it was considered desirable to defer the adoption of a more distinctive name until this unit had been given further consideration by others who would have use for a unit of this type. This new unit is defined by the statement that two amounts of power differ by one transmission unit when they are in the ratio of $1^{.1}$, and any two amounts of power differ by N transmission units when they are in the ratio of $10^{N(.1)}$. In accordance with this, the number of transmission units corresponding to the ratio of any two powers is ten times the common logarithm of that ratio.

For a unit of this kind, it is evidently desirable to have universal use. Accordingly, the Bell System, prior to its adoption of the tranmission unit, discussed this matter with various foreign telephone administrations, and suggested their consideration of the use of the proposed "transmission unit." A number of these administrations expressed a favorable attitude towards this unit.

In 1924 there was organized the International Advisory Committee on Long Distance Telephony in Europe. The purpose of this committee, which is composed of representatives of the various telephone administrations of Europe, is to recommend standards and practises for the development of telephone service between the European countries. One of the early considerations of this committee was this proposal of the universal standardization of a unit for telephone transmission work. This brought forth a difference of view, since some of the countries represented on this committee wished to continue their use of a unit based on naperian or natural logarithms, for which the basic power ratio is e^2. The characteristics of the unit based on decimal logarithms and that based on natural logarithms and their relative merits were discussed in a number of papers which were published at that time, and so need not be rehearsed here.

At the request of the International Advisory Committee, representatives of the Bell System attended some of their meetings at which this matter was discussed. In this joint consideration there arose the suggestion that the fundamental unit on the decimal basis be defined to be equal in magnitude to that of ten transmission units, so that the basic power ratio would be 10^1. The units proposed thus came to one based on the power ratio of 10^1 and the other on the power ratio of e^2, with the provision that decimal submultiples of either unit could be employed, using the customary prefixes to give the proper indication. On this basis, the numbers of the two kinds of units corresponding to a given power ratio, differ by about 15 per cent. It was further suggested that the naperian unit be called the "neper" and that the fundamental decimal unit be called the "bel," these names being derived respectively from the names of Napier, the inventor of natural logarithms, and Alexander Graham Bell.

These joint considerations have had the following results. The European International Advisory Committee has recommended to the various European telephone administrations that they adopt either the decimal or naperian unit and designate them the "bel" and "neper" respectively. The Bell System has adopted the name "decibel" for the "transmission unit," based on a power ratio of $10^{.1}$. This is in accordance with the terminology for the decimal unit, the prefix "deci" being the usual one for indicating a one-tenth relation. For convenience, the symbol "db" will be employed to indicate the name "decibel."—*Bell System Tech. Journal*, January, 1929.

RADIO CONTROL OF STREET LAMPS

The Edison Electric Illuminating Company of Boston is now using in some of its equipment, a small radio receiving set installed in the base of each lamp post. When waves of 720 cycles a second are sent along the light wires, the receiver moves a switch which connects the individual lamp with the lighting circuit. When the frequency is 480 cycles the receiver pulls a switch which disconnects the lamp, all lamps in a particular circuit going on and off at the same instant.

Separation of Stray Load Losses in A-C. Generators[1]

BY M. C. HOLMES[2]

Associate, A. I. E. E.

Synopsis.—This paper describes an experimental attempt to separate the stray load losses of large a-c. turbine generators, making use of the fact that the loss in any of the various parts is proportional to the initial rate of temperature rise in that part. Comparisons are made between tests conducted with rotor structure removed and short-circuit tests.

Introduction

In the "separate loss" method of calculating the efficiency of large a-c. generators, it is customary to calculate the stray load losses from short-circuit tests by subtracting the known losses, such as friction and windage, field copper, and d-c. armature copper loss, from the measured losses. The remainder is taken as the stray load loss.

It is generally considered that the stray load loss determined from short-circuit tests, especially in turbine alternators or in general in high armature reaction alternators, is too high. It has been suggested by Mr. Roth[3] that tests made with the rotor structure removed and full-load current circulating in the armature windings gives results which are much nearer actual load conditions. Whether these views are accepted or not, it is a fact that the stray load losses of large turbine alternators as determined from short-circuit tests, are often as large and sometimes larger than the full-load armature copper loss. Thus it is important that we should know more about the components of these losses if we are to make any real progress toward improving the design and increasing the efficiency of our machines.

Object

The object of this paper is to describe some tests made in cooperation with the Massachusetts Institute of Technology and the General Electric Company in an attempt to separate the stray load losses in the stators of some large high-speed turbine alternators.

Method

The method of separating these losses was suggested in 1917 by Mr. Dawson in his discussion of Mr. Kelly's paper on *Internal Temperature of A-C. Generators*[4] presented at the New York meeting of the A. I. E. E. of that year, and again in detail by Messrs. Laffoon and Calvert.[5] Briefly it is as follows: With all parts of the machine at the same temperature, voltage is suddenly applied and current caused to flow in the windings. Temperature readings are taken at frequent intervals, and temperature-time curves plotted for the various parts. Initially, all of the heat generated is stored and is utilized in raising the temperature. Knowing, then the initial rate of temperature rise of the part and its heat capacity, the loss in watts may be calculated. Thus, if we consider a small element of material of volume v, whose specific heat is k, and whose density is ρ, then the rate at which the heat content of the element is increased is

$$\frac{dH}{dt} = k \rho v \frac{d\theta}{dt}$$

Where θ is the temperature and H is the heat content.

If $\frac{dH}{dt}$ be measured in watts, ρ in grams per cu. cent., v in cubic inches and $\frac{d\theta}{dt}$ in deg. cent. per min., the following expression is obtained for the loss in watts per cubic inch in terms of the initial rate of temperature rise,

$$\text{watts per cu. in.} = 1.142\, k \rho \frac{d\theta}{dt}$$

and using the following values for k and ρ,

Material	k	ρ
Copper	0.0925	8.9
Cast iron	0.119	7.35
Wrought iron	0.115	7.86

this equation becomes,

Watts per cu. in. = 0.94 X for copper
Watts per cu. in. = 1.00 X for cast iron
Watts per cu. in. = 1.03 X for wrought iron

where X is the initial rate of temperature rise in deg. cent. per minute.

Tests

The tests were made with the rotor structure removed and current circulating in the armature windings. This method was used for two reasons; first, the input to the stator could be measured, thereby furnishing a check upon the total losses as determined separately from the temperature-time characteristics of the parts; second, the total losses could be compared with values

1. Results of an investigation carried on in cooperation with the Massachusetts Institute of Technology and the General Electric Company.
2. Department of Electrical Engineering, University of Illinois.
3. See Bibliography No. 1. Printed complete herein.
4. See Bibliography, No. 7.
5. See Bibliography No. 4.

obtained from previously determined short-circuit tests.

Some representative curves are shown for one of the machines tested, a non-salient, two-pole, three-phase, a-c. turbine generator, with solid field, rated 5000 kw., 3600 rev. per min., and delivering a full-load current of 7518 amperes at a potential of 480 volts and a power factor of 80 per cent. The stator has 24 slots and the windings are Y-connected. The machine is practically unique with its low-voltage and high-current capacity.

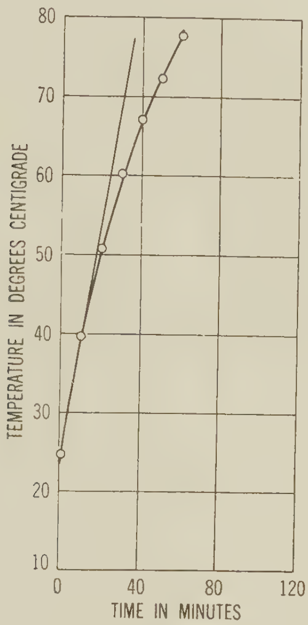


Fig. 1—Temperature Rise in End Fingers

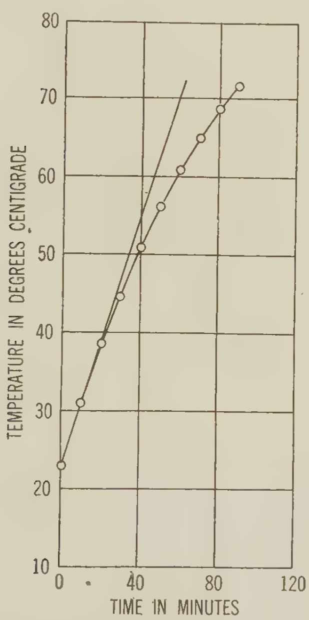


Fig. 2—Temperature Rise in Stator Teeth—Section No. 1

Results

Figs. 1 to 6 are some typical temperature-time curves with tangents drawn to show the initial rate of temperature rise. The points on the curves represent average values. Temperatures were measured by thermometers in the accessible parts and by resistance-temperature indicators in the inaccessible parts.

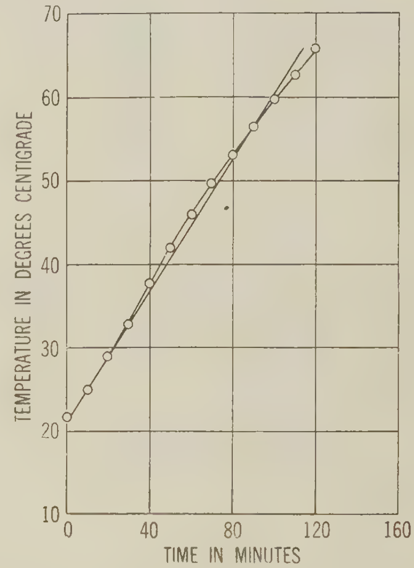


Fig. 3—Temperature Rise in Stator Teeth—Section No. 2

From such curves the losses in the various parts were calculated by the method already outlined.

TABLE I

INITIAL RATE OF TEMPERATURE RISE

Part		Deg. cent. per min.	Watts per cu. in.
End fingers		1.49	1.54
Binding rings		0.715	0.715
Flange, inner edge		0.705	0.705
Flange, outer edge		0.300	0.300
Core		0.022	0.023
Teeth	Sec. No. 1	00.800	0.825
	Sec. No. 2	0.400	0.412
	Sec. No. 3	0.280	0.289
	Sec. No. 4	0.260	0.269
	Sec. No. 7	0.265	0.273
	Sec. No. 10	0.255	0.263
	Sec. No. 13	0.250	0.258

TABLE II

SUMMARY OF LOSS CALCULATIONS

Part	Calculated loss	Loss by wattmeter
Armature copper	21,740	:
Flanges	5,700	:
Teeth	3,140	:
End fingers	2,090	:
Core	1,050	:
Binding rings	840	:
Total	34,560 watts	34,400 watts

It should be noted that the armature copper loss is not strictly a "test" loss. It was calculated from the current and resistance, taking account of circulating current losses, according to the methods described by Mr. I. H. Summers.[6]

TABLE III
STATOR STRAY LOAD LOSSES

Part	Loss in watts from test	Per cent of total
Armature copper[7] ..	12,300	49.0
Flanges............	5,700	22.7
Teeth..............	3,140	12.5
End fingers.........	2,090	8.3
Core...............	1,050	4.2
Binding rings.......	840	3.3
Total..............	25,120	100.0

Table III shows the separate stray load losses, the armature copper loss being simply the additional copper loss caused by the circulating currents which are set up by the load currents.

Fig. 8 shows graphically how the loss in the teeth varied from the end section to the middle section of the machine.

Incidentally, one important result of the test has

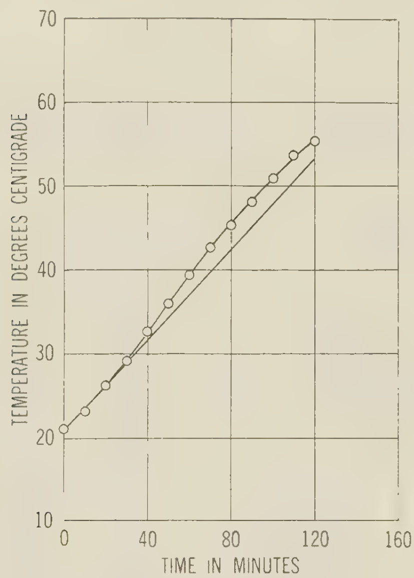


FIG. 4—TEMPERATURE RISE IN STATOR TEETH—SECTION NO. 3

been the discovery that certain steel studs holding bus rings, terminal leads, etc., were, due to induction from the heavy armature currents, becoming dangerously hot. These studs were replaced with brass ones and the temperature lowered to a comparatively small fraction of that previously indicated.

From the results it is seen that a large part of the stray loss occurs in certain solid iron parts such as flanges, binding rings, and end fingers. This offers a field for further investigation in the reduction of stray losses. It is possible that some method of shielding would prove effective, or that the losses could be reduced by increasing the distance between the iron of the flanges and the copper of the end turns. Perhaps some non-magnetic material could be used in their construction, in which connection it is interesting to note here that a non-magnetic material has been used for the end fingers and binding rings in one of the large machines built since these tests, with a marked decrease in the operating temperatures of those parts.

The curve of Fig. 8 shows that the loss in the end

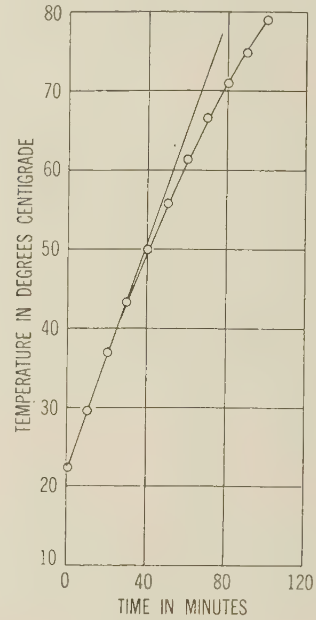


FIG. 5—TEMPERATURE RISE IN OUTER BINDING RING

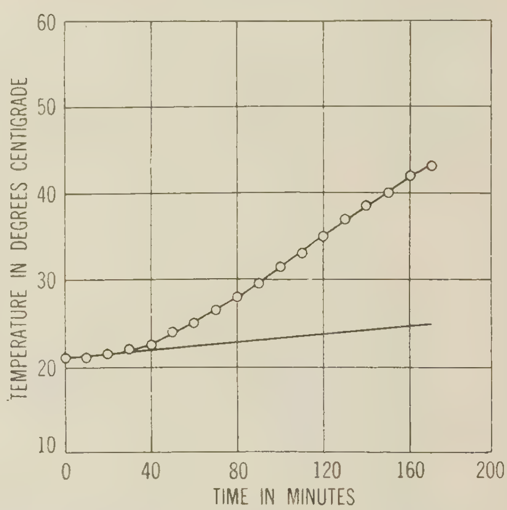


FIG. 6—TEMPERATURE RISE IN CORE, MID-SECTION

sections of the stator teeth is much higher than in any of the other sections. This was expected and is due to the fact that the flux is no longer parallel to the laminations but has been crowded out at the ends of the machine in a direction perpendicular to the laminations, making them no longer effective in reducing eddy currents.

Several of the temperature–time curves show the effect of heat received from neighboring parts, especially the core. This does not effect the accuracy of the results, however, for the tangent always shows the initial rate of temperature rise and so does not include the later effects of heat transfer.

It is seen that the copper loss constitutes the largest

6. See Bibliography No. 2.
7. This value obtained by subtracting $I^2 R$ loss from the total copper loss and is not strictly a "test" loss.

part of the stray loss in the stator of this particular machine. This is due to the circulating currents which are not completely neutralized by the 180 deg. transposition used, and also to the high strand-loss factor of the winding.

Comparison with Short-Circuit Tests (Pole-Face Losses)

The stray load losses for this machine as determined from the conventional short-circuit tests amounted to almost three times the stray load losses in the stator as determined from these tests with rotor structure removed. This would seem to indicate that the stray load losses for this machine, when measured by the usual short-circuit tests, must consist largely of pole-face losses in the rotor; that is, approximately 66 per cent consists of pole-face loss. This of course assumes that the losses in the stators are approximately the same for either method. For a first approximation, this is not an unreasonable assumption, especially when it is considered that this machine had a ⅞-in. air-gap. The copper loss would be the same in either case. The only losses that could change materially would be those in the core and teeth, the former of which is small. Furthermore, any increase in tooth loss on a short circuit would be partly compensated for by the increased core loss measured with rotor removed, for there is no loss in the core back of the teeth on short circuit except that due to the small amount of flux necessary to overcome the resistance drop of the windings and the leakage reactance drop of the end turns. Calculations from

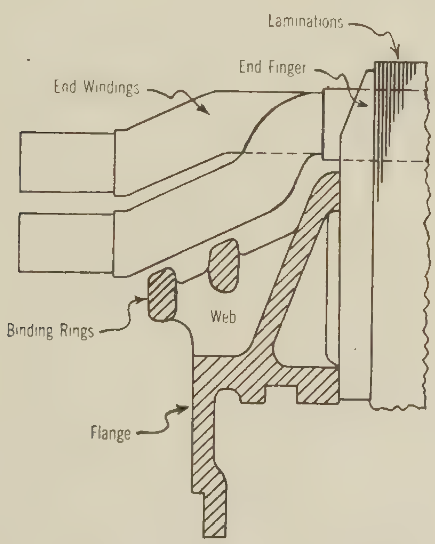


Fig. 7—Sketch Showing Arrangement of End Windings, Fingers, Binding Rings, and Flanges

empirical formulas also indicate that this value of pole face loss is quite reasonable, especially when it is considered that there were 3760 ampere per slot, and the pole-face losses increase according to some higher power of the ampere conductors per slot and the tooth width.

From a comparison of the two tests, it is evident that the assertion made by Mr. Roth to the effect that the stray load losses determined from tests made with the rotor structure removed more nearly represents actual conditions than from tests on short circuit, does not always hold, especially in the case of machines with large pole-face losses. Any discussion, however, as to how closely the losses determined by these two methods represents the actual load losses, is beyond the scope of this paper. It is sufficient merely to point out that the losses as here determined actually represent the distribution of stray losses as determined by present conven-

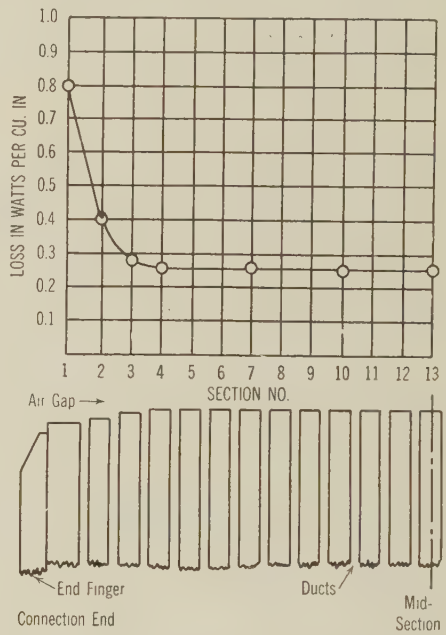


Fig. 8—Cross-Section of Core Showing Distribution of Tooth Loss

tional methods of test; they are the losses entering into efficiency calculations, and as such are important.

In conclusion, the author wishes to acknowledge his indebtedness to Mr. W. F. Dawson of the General Electric Company, who was responsible for the initiation of the project and the carrying out of the tests. Grateful acknowledgment is also made to Doctor H. B. Dwight of the Massachusetts Institute of Technology, and to Mr. I. H. Summers of the General Electric Company, for their aid and helpful criticisms during the investigations.

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Abridgment of

Insulation Tests of Electrical Machinery

Before and After Being Placed in Service

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and

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Synopsis.—*The A. I. E. E. Standards have provided high-potential test values as a means of establishing a standard basis of design and construction of insulation. Many purchasers test equipment after installation before placing it in service to be sure that the connections and equipment are in a safe condition for service. It is recommended that a standard test voltage be established that may be used under these conditions.*

It also seems to be advisable that suitable rules should be set up governing test voltages that should be used in a maintenance program. Periodic observations of the insulation resistance are suggested as substitute or supplemental tests. If there is a general desire that rules of this sort should be made, it is proper that the Institute should enter this new field of standardization.

* * * * *

THE work of standardization performed by the American Institute of Electrical Engineers has been and is one of the most valuable undertakings that lie within its field of activities. This standardization has been primarily in the nature of establishing rating standards by which equipment of different manufacturers can be compared. While these standards have been based upon what is believed to be typical or average operating conditions they obviously are not standards for operation.

There is a rather decided opinion among many engineers that the Institute should undertake the development of standards for operation in fields in which they can be established.

One of the fields in which it is believed such standards can be developed is that of high-potential tests. These tests are not offered as standards of comparison of equipment nor as acceptance tests for purchasers from manufacturers, except as possibly determined by special contracts, but are intended as operating guides. They are an attempt to crystalize a variety of opinion as to what should be an adequate and safe test to determine the suitability of equipment for service, for those who wish to employ high-potential tests for this purpose.

This paper endeavors to present the subject in two parts; first, a test for new equipment before being placed in service, and second, a high-potential test for occasional check on equipment that is or has been in service. The first part has been prepared chiefly by the first author and the second part by the second author of the paper.

Part I

Insulation Tests for Initial Operation

High-potential testing may be roughly grouped in three general classes, each with a distinct purpose in view, but all with the fundamental object of determining the ability of the equipment to withstand the normal and abnormal potentials that may be reasonably expected under the operating conditions for which the device is designed.

The first group of tests is intended to determine the characteristics of the material or design in question.

The tests of the second class are those carried on to discover factory errors in the manufacture of equipment or details of design.

The third class of high-potential tests is made to determine the adequacy of equipment for service, to discover whether some accident has happened to the equipment since the factory test prior to its final connection to the lines ready for service or whether after once having been placed in service there has been sufficient deterioration of material or accidental damage to make the equipment unsafe for service.

The present rules of the Institute covering high-potential tests were primarily adopted as a means of establishing minimum standards of design for ordinary operating conditions, and are essentially the result of the experience that the equipment so designed will have a reasonable life under normal operating stresses including such overpotential surges as are commonly met with under ordinary operating conditions. The tests were further intended to insure the insulation meeting the expectations of design.

Subsequent to the tests at the factory, there are finishing touches sometimes added. Machinery is crated, shipped, and connected ready for service in the final installation and during this handling process, accidents to the equipment occasionally occur, which, if not discovered prior to placing in service, may result in serious damage to it, other equipment, and to the service rendered by the purchaser. These defects cannot always be discovered by observation.

These tests are not ordinarily considered acceptance tests unless the equipment is delivered and erected by the manufacturer, as the equipment commonly passes out of control of the manufacturer when it leaves the

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factory, but are intended to cover the period and work between shipment and operation.

Obviously, equipment which is assembled on the premises of the purchaser without a complete factory test should receive the same test as that previously assembled and tested at the factory.

As a generally accepted example of this practise, a test is placed on cable before it leaves the factory to discover defects in the manufacture of the cable and after the somewhat severe process of pulling into the ducts, a further test is placed upon it and the joints to be sure that the completed cable is ready for service. It is recognized that the process of installation certainly reduces the strength of the insulation at various points and consequently the tests after installation are lower than those at the factory, or one might rather say the factory tests are somewhat higher than the standards set after installation to make due allowance for the deterioration that results from handling.

Similarly, the various parts of assembled equipment are given individual high-potential tests before they are assembled in the completed machine and the value of the tests of the various parts is higher than that of the completed piece of equipment. The final tests of the completed machine are to insure that no damage has resulted to the individual parts and to place a test upon such connections as cannot be effectively tested before the final assembly. Allowance is made for the deterioration of portions of the equipment and the rules recognize a test on the completed assembly of 15 per cent lower than the tests on the part receiving the lowest individual test.

In spite of the very good reason for testing equipment before energizing with service voltage, many careful purchasers of equipment forego this final check for one or both of two reasons. First, there is the general feeling that each high-potential; test causes some permanent damage to the insulation, and second, that the insulation may not be in as good condition as before leaving the factory.

The question of the voltage strain and damage to the insulation is one on which opinion is very widely separated. That there is probably some slight deterioration with each high-potential strain is commonly believed and one school of thought believes that in the long run there are more failures and more damage as a result of the cumulative deterioration of equipment in reasonably condition as a result of the repeated strains imposed by tests than occur due to the normal deterioration of insulation and the consequent failures that are not anticipated by test. Certain insulating mediums such as oil and inorganic substances seem to be affected little or not at all by high potential stresses of any number of repetitions. The actual effect of high-potential stress on fibrous insulation is much more uncertain. When the insulation is stressed to a point near that of failure, the matter of time and duration is of great importance in the performance of the material and yet we know that many times during its life insulation is subjected to brief overvoltage stresses of two or three times normal voltage. It would seem that an additional application of overvoltage of short duration or of a value reasonably below the breakdown value of the insulation placed upon the equipment before going into service would not have any appreciable effect upon the life of the insulation. It is hoped that out of the various studies which are now being conducted on what actually takes place when insulation fails will come information that will point to the answer of this much discussed question of repeated tests. The tests reported by F. M. Clark on *Dielectric Properties of Fibrous Insulation*, (A. I. E. E. TRANS., Vol. XLV, 1925, p. 193) indicate that for a certain type of insulation the breakdown voltage is actually increased by a number of previous high-voltage tests, probably due to a drying out process, but that the insulation is permanently damaged by too large a number of overvoltage applications. The further conduct of such tests on various materials, with relative magnitudes of voltage and time, will do much to settle this question.

It is obvious that equipment should not be subjected to high-potential tests unless the insulation is in such a condition that it may be reasonably expected to withstand the test without damage or failure. The equipment must be carefully gone over to be sure that there are no apparent points of weakness or damaged parts of insulation, to be sure that there is no foreign material in the equipment that might cause a breakdown, that it is free from an accumulation of dust which might result in a failure, and above all, one must be sure that the insulation is free from moisture.

Similar precautions are and should be taken before equipment is placed in service even though no high-potential test is made. It should not be considered safe to operate equipment that is not in a condition to withstand safely an overvoltage test. Low-voltage equipment in which the insulating value of insulation is far beyond that required by the ordinary operating voltage may sometimes be operated with a fair degree of safety under conditions in which it would not withstand a high-potential test without serious danger of damage. Such conditions are rather the exception when considering equipment which a purchaser would ordinarily undertake to test.

Due to the fact that it is desirable not to cause any undue deterioration of the insulation by the test procedure, and that factory tests have already been made to insure against inherent defects in the insulation, it would seem reasonable that the test before operation should be somewhat less severe than at the factory. It should be searching enough to discover damage of the insulation that may later develop into a serious fault. The reduction of test may be in either time or magnitude of voltage, or both. A number of arguments has been advanced for a reduction of as much as 25 per cent of the original test voltage, while others believe

that the reduction should not be more than 15 per cent to correspond with the existing standards for the reduction in test voltage of assembled equipment while still other arguments are advanced for maintaining the magnitude of the original factory test voltage but reducing the time of test from one minute to momentary. The British standards recognize the establishment of such a test voltage for this purpose and have set it at 25 per cent below the factory test voltage.

In view of the differences in opinion as to what such a test voltage should be, it would seem desirable for the Institute to broaden its range of standards and include a standard of test voltage that may be used when desired by the purchaser when placing new equipment in service.

This standard is not intended to be mandatory, but should be considered as establishing a standard test voltage that may be applied at the option of the purchaser, not as an acceptance test, but to assure himself so far as is possible that neither the equipment nor the service will be damaged by some accident that may have occurred to the apparatus.

It would appear that there is a field for such a standard and it is recommended for further consideration that the Institute establish a standard of test voltage that may be used for new equipment after installation of 85 per cent of the factory test voltage of the equipment connected at the time of the test receiving the lowest factory test and for a period of one minute.

Part II

Insulation Tests of Electrical Machinery In Service

For the same reason that it is desirable to set up a standard practise for testing the insulation of electrical apparatus at the time of initial installation, it is also desirable to establish a rule or recommendation as to what tests would be suitable for a maintenance program.

The lack of any semblance of uniformity in practise in this respect has been drawn to the attention of the Committee on Electrical Machinery and after a careful consideration this committee has decided that a discussion of this subject should be presented to the membership of the Institute in the hope that it may lead to an agreement of some sort. Previous attempts have been made to formulate some standard practise or recommendation of this kind and probably the best efforts in this direction have been made by the Apparatus Committee of the National Electric Light Association by whom questionnaires were circulated among members for the purpose of determining their practises and the degree of satisfactory results. The reports of this committee indicate that the practises of the different members are so various that it is not practicable to choose any one as representing a general preference or giving better results than the others.

In considering suitable means of checking the condition of insulation for use in a maintenance program it is but natural to turn to the present A. I. E. E. standards for guidance. But the insulation test voltages set up in these standards are designed to insure that the insulation has sufficient dielectric strength to allow for a certain amount of deterioration and still be sufficient to withstand the voltages that may be impressed upon it under operating conditions and in this sense is in the nature of an expected life test. It therefore appears that it should not be expected that after a period of operation in which undoubtedly some deterioration has taken place the insulation should withstand the same test as when new.

If the deterioration of insulation followed a known rate of reduction in dielectric strength under operation conditions it would be a simple matter to set up a schedule covering the expected strength over a given length of time and the corresponding test voltages. In that event tests would serve principally to search out possible mechanical injuries. But the life of insulation is an indefinite term. It contains, however, the element of time and is dependent upon the temperature to which it has been subjected as well as various other conditions. In their paper on *Temperature and Electrical Insulation*,[3] Steinmetz and Lamme offered curves showing the relationship between length of life and temperature. Fig. 1 is a reproduction of their curve for Class A insulation. The curve for Class B insulation is of the same type. In these curves the length of life does not refer to the time in which the insulation will entirely lose its dielectric strength but as explained by the authors it has to do with the time at which the fabric or varnish becomes brittle and loses it mechanical strength. The life of an insulation in this sense may be spent entirely and yet retain approximately its original dielectric strength provided it has not been mechanically injured. Therefore, the term "life" as used in connection with accepted practises in testing insulating materials is somewhat misleading, for it does not have reference to its dielectric property. The useful

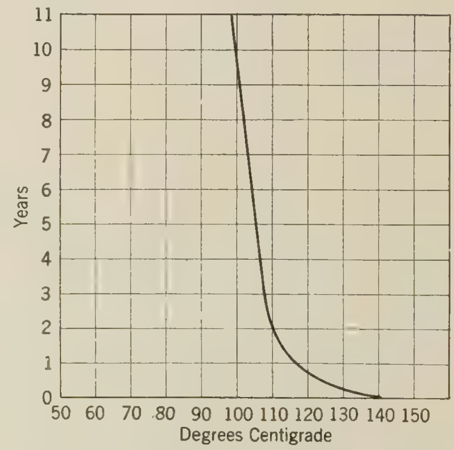

Fig. 1—Insulation Tests of Electrical Machines in Service

3. A. I. E. E. Trans., Vol XXXII, 1913, pp. 79-89.

life of an insulation is not dependent upon the effect of temperature and time alone but also upon various other conditions which tend to destroy it by mechanical forces. It is reasonable, then, that the insulation should be expected to last an indefinitely long time if it were protected against mechanical injury, barring, of course, the effect of excessively high temperatures which would change the chemical composition or structure of the insulation. The common causes of mechanical injury are vibration and distortion due to temperature changes and electromagnetic forces. These causes are present in widely varying degrees due to differences in design and conditions of operations and it is, therefore, impractical to formulate a relationship between length of service and dielectric strength to indicate what may be expected of any particular type or class of insulation in a given kind of machine or to define a maximum test voltage that the insulation could be expected to withstand at given intervals.

But supposing that a relationship between time of operation and dielectric strength could be established for certain average conditions, would it be of much practical value in a maintenance program? Conceivably it might be used as a guide to indicate the time when the windings should be reinsulated or replaced and what test it would withstand at any given time. It does not seem reasonable that a maintenance program should call for a test at say double voltage at the end of one year of operation, 50 per cent overvoltage at the end of three years, and 25 per cent overvoltage at the end of five years if the 25 per cent overvoltage test gives sufficient insurance against breakdown during the ensuing period of operation and if uninterrupted service is of equal importance. It would appear, therefore, that the value of the test voltage should be chosen with respect to the maximum stresses that would occur in operation rather than the probable actual dielectric strength. If, then, operating conditions are defined it becomes possible to set up a value for the test voltage.

It is seldom that machines are required to operate at voltages above 10 per cent over normal. This is especially true of machines connected to low-voltage systems. Important a-c. generators are provided with overvoltage relays to limit abnormal rises of voltage to approximately 25 per cent overvoltage and the neutral point is grounded for relay protection of the winding. Under normal operating conditions the voltage between machine terminals and ground is 58 per cent of the rated terminal voltage and under an abnormal condition of 25 per cent overvoltage this would be increased to approximately 72½ per cent of the rated voltage. An insulation test between winding and ground at rated voltage would impose a stress approximately 38 per cent greater than would occur when the machine voltage is raised to 25 per cent above the rated voltages. Such a test would insure a sufficient margin in the dielectric strength for further service without risk of failure to ground. Such a test would not, however, be a check on the condition of the insulation between phases but by testing one phase at a time with the other two phases grounded the insulation between coils in different phases would be tested at a voltage higher than the operating voltage in proportion to their distance in the circuit from the terminals. The insulation between terminals would not be tested at a higher voltage than the normal operating voltage and there would not be any assurance of a margin in the condition of the insulation between phases.

By separating the tests and making one test to ground and another between phases, two different values of test voltage could be used, each suitable for its purpose without imposing an excessive voltage where a lower test is sufficient assuming that the rated voltage is sufficient for testing between winding and ground a higher voltage than could be chosen to test between phases which would produce the same relative overvoltage stress on the insulation between phases. This result would be obtained by testing between phases at 175 per cent of rated voltage with none of the phases grounded.

To those who are accustomed to associate all insulation test voltages with those that have been prescribed in the A. I. E. E. standards for new machinery, the proposed test voltage between winding and ground appears to be ridiculously low yet it fulfills the requirements. The proposed practise is not new. It has been used by the service departments of at least two of the large manufacturing companies when overhauling electrical apparatus for their clients. Their experience is that this program has produced satisfactory results. On the other hand, the author has received many expressions of opinion from engineers who are responsible for the operation of electrical apparatus that the test voltage to ground should not be less than 150 per cent of the rated voltage. Nevertheless, many instances have been cited of machines which have given years of service after the insulation has reached such a condition that it would unquestionably have failed at test voltages only slightly higher than normal. It is a commendable practise to maintain apparatus in a first class condition, but the greater reliability thus obtained does not always justify the cost. It is to be expected that as the test voltage is increased, so is the frequency of repairs increased.

It is generally agreed that high-potential tests of insulation do lasting damage to it and for that reason all unnecessary tests of that nature should be avoided. A maintenance program that would omit high-potential tests and substitute some other test that would not damage the insulation is by far the better. While comparatively little experience has been obtained it is believed that the periodic measurement of the insulation resistance of windings would give warning of dangerous conditions that may develop. A program covering the determination of the insulation resistance at regular intervals during the period of operation and high-

potential tests at times of overhauling when it would be convenient to make repairs should afford a fair degree of freedom from inopportune shut-downs. The adoption of such a scheme would call for the exercise of much good judgment to obtain satisfactory results and in the absence of sufficient practical experience upon which good judgment can be based, it is advisable to set up a recommended practise in applying high-potential tests.

In view of the divergence of opinion regarding the value of test voltage that should be used as between rated voltage to ground and 150 per cent rated voltage a compromise might be struck at 125 per cent of rated voltage. In order to employ the same form of rule as now used for new machines a constant of 500 volts may be added to this value. Such a rule would then read as follows:

> It is recommended that except for distribution transformers which may offer hazards to life, the dielectric tests of windings of machines in service shall be at 125 per cent of the rated voltage plus 500 volts. When it is convenient to separate the phase windings a further test between phases shall be made at 175 per cent of rated voltage plus 500 volts.

Conclusion

The theme of this joint paper, therefore, is a plea that the Institute enlarge its scope of operations to meet what appears to be a genuine need of the membership at large. This need is twofold: first, for a basis of insulation testing prior to initial operation, and second, a similar basis for the operating period of this apparatus.

As a basis for consideration and possible acceptance by the Institute, these recommendations have been offered, which are in brief:

> For initial operation—a voltage 85 per cent of factory test for one minute, based on connected equipment receiving lowest factory test, and
>
> For maintenance—a test to ground of 125 per cent rated voltage plus 500; and between phases, 175 per cent plus 500 volts—supplemented by periodic measurements of insulation resistance.

Abridgment of

Line-Start Induction Motors

BY C. J. KOCH*[1]
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Importance of Line Start Motors

Many manufacturers of polyphase squirrel-cage induction motors in the integral horsepower sizes have now added to their other products, a modified form of squirrel-cage motor in which the starting current is reduced below that of the standard squirrel-cage motor. The reduction in starting current is sufficient to warrant the power companies throughout this country to permit the starting of these motors directly across the line without the use of a starting compensator. This type of motor is now sold under a variety of trade names, such as line-start motors, auto-start motors, double-deck motors, double squirrel-cage motors, high-reactance motors, etc.

Because the use of this motor makes unnecessary the purchase and maintenance of a starting compensator, the popularity of the type is assured. The extent to which the standard squirrel-cage motor is already superseded indicates the popularity which the line-start motor will have in the future.

High-Resistance and High-Reactance Motors Relation of Maximum Torque to Starting Current

Line-start motors are of two fundamental types, differing in the manner in which the starting current is reduced below that of the standard squirrel-cage motor. These types may properly be called the high-reactance type and the high-resistance type.

The high-resistance line-start motor may be considered as derived from the standard squirrel-cage motor by a reduction in the total amount of magnetic flux per pole, *i. e.*, by an increase in the number of turns per coil in the stator winding. The starting current will vary inversely as the square of the number of turns per stator coil. At the same time, the starting torque and the maximum running torque will be reduced in the same proportion. The starting torque may be increased again to any desired value within limits by decreasing the size of the rotor bars but this leaves the amount of maximum torque unaffected. In the high-resistance type of motor, therefore, the maximum torque and the starting current are quite closely proportional, any reduction in starting current resulting in a corresponding reduction in maximum torque.

In the design of a high-reactance line-start motor, the starting current is limited by increasing the leakage reactance of the motor. This is usually done by providing for each rotor bar a leakage path of comparatively low reluctance. If both the rotor and stator resistance were zero the starting current would be exactly inversely proportional to the leakage reactance. Actually the starting current will not decrease as rapidly as the leakage reactance is increased, due to the effect

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of resistance, but the departure from proportionality is not wide. In the same way, the maximum running torque which the motor will develop is approximately inversely proportional to the leakage reactance. In the high-reactance type of motor as well as in the high-resistance motor, therefore, the starting current and the maximum running torque are roughly proportional.

It follows that for both types of motors, the minimum starting current for which they can be designed depends upon the minimum value of the maximum torque which is accepted as a standard for general purpose motors.

At the present time 200 per cent maximum torque is conceded to be high enough for general purpose applications.

By experience it is found that high-reactance line-start motors built to have a starting current of 6 amperes per hp. on a 440-volt 60-cycle circuit will develop 200 per cent maximum torque with a slight margin and will have efficiencies comparing favorably with those of standard motors. This value of starting current represents therefore a minimum value for general purpose line-start motors.

Only motors for use in special applications where the torque requirements and voltage conditions are definitely known justify any lower value.

The maximum torque obtainable with the high-resistance type motor is slightly higher than that of the high-reactance motor for the same starting torque and current. In spite of this it is not practicable to reduce the starting current of the high-resistance type motor below 6 amperes per hp. at 440 volts, owing to the sacrifice in efficiency involved and the resulting increase in heating of the motor.

Limitations of Size of Line-Start Motors

The relation existing between amperes per hp. of starting current and maximum torque given in the preceding paragraphs is approximate only, but within the range of its approximation the relationship is independent of the motor size. If 6 amperes per hp. at 440 volts was an acceptable value of starting current for line-start motors irrespective of size, it would be possible to develop a line of general purpose line-start motors with 200 per cent maximum torque in any size requested. Actually this is not the case.

The most widely accepted rules regulating starting currents for 60-cycle circuits, the so-called "N. E. L. A. rules," are on a sliding scale, the permissible starting currents becoming more stringent for the higher hp. ratings. This imposes a definite limit to the size of a line-start motor which can develop 200 per cent maximum torque and still meet the starting current prescribed by these rules.

Table I is an extract from the N. E. L. A. rules showing the prescribed starting current for three-phase motors on 440-volt 60-cycle circuits.

The stringency of the rules at higher horsepowers will be noticed. Thus a 10-hp. motor is allowed a starting current of 7.06 amperes per hp., a 30-hp. motor is allowed 6 amperes per hp., and any motor above 50 hp. is allowed a starting current of only 4 amperes per hp.

"Limited maximum torque" motors may be built to comply with the N. E. L. A. rules in any horsepower rating desired.

TABLE I

Horsepower	Starting current 3-phase—440 volts 60-cycles
3	30
5	43.3
7½	58
10	70.5
15	98.5
20	125
30	180
40	190
50	200
100	400

Normal and High Starting Torque Motors

Line-start motors of two varieties are now built as standardized products in sizes from 5 hp. to 30 hp., differentiated from one another by the amount of starting torque developed. These are known as "normal-torque" motors and "high-torque" motors. Although differing in starting torque, both kinds of motors for the same rating are designed to have the same starting current, *i. e.*, the N. E. L. A. recommendation for that horsepower.

Normal-torque line-start motors may be of either the high-resistance or the high-reactance type but high-torque motors are always of the high-reactance type.

The normal-torque motor has a starting torque of about 150 per cent of full-load torque. This is slightly higher than that developed by a standard squirrel-cage motor when started on the 80 per cent tap of a starting compensator. The normal-torque motor is therefore applicable for general purpose work and is intended to be a substitute for the squirrel-cage motor and compensator.

The high-torque motor is designed to have from 225 per cent to 250 per cent starting torque and fills the special torque requirements of such loads as ammonia compressors, certain chain conveyors, and other applications where the torque requirements are severe at starting.

Comparative torque curves of a typical high-torque and normal-torque line-start motor are shown in Fig. 1.

Effect of Saturation Upon the Starting Current

The starting current of line-start motors is usually measured with the rotor blocked at standstill and with either full voltage or a reduced value of voltage applied at the terminals. In the latter case the starting current value at full voltage is found from the value

measured at reduced voltage, assuming the starting current and the terminal voltage to be proportional. This proportionality does not actually hold true. The starting current at full voltage may be from 8 per cent to 15 per cent higher than the value extrapolated from reduced voltage readings. This is due to the fact that at full voltage the ampere conductors per slot in both the stator and rotor is higher than at reduced voltage and more saturation of the leakage flux paths occurs. This results in an appreciable decrease in leakage reactance at full voltage.

It follows that the line-start motor which meets the N. E. L. A. rules at full voltage must have about 10 per cent more reactance running than a similar motor which meets the rules only at reduced voltage. The first motor is therefore under a certain handicap and has a lower power factor and a lower maximum torque than the second motor.

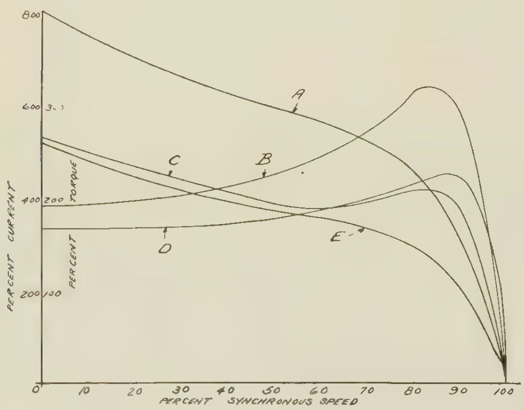

Fig. 1

a. Current curve—Standard squirrel-cage motor
b. Torque curve—Standard squirrel-cage motor
c. Torque curve—High-torque high-reactance motor
d. Torque curve—Normal-torque high-reactance motor
e. Current curve—Normal-torque and high-torque high-reactance motor

The purchaser of a line-start motor is of course interested in knowing the actual starting current of the motor at full voltage, so that the better practise is to design line-start motors to meet the N. E. L. A. rules actually at full voltage. The N. E. L. A. recommendations, however, recognize and accept the measurement by extrapolation from reduced voltage.

Operating Characteristics

Normal-Torque High-Reactance Motors

The normal torque high-reactance motor is the line-start motor of the high-reactance type designed for general purpose application and having 150 per cent starting torque.

At full load, the leakage reactance of this motor is higher than that of a similar standard squirrel-cage motor. This difference results from the following three causes.

1. The reactance has been increased in order to limit the starting current.
2. Saturation of the leakage paths with full voltage starting.
3. The leakage inductance of a high-reactance rotor slot is greater at synchronous speed than at standstill.

The total additional reactance represented by these three causes constitutes an additional reactive kv-a. drawn from the line by the motor, the magnitude of which depends on the load. At full load, this kv-a. will result in the normal-torque high-reactance motor having a power factor from 2 per cent to 4 per cent lower than that of a standard motor of the same size. At reduced values of load, this difference in power factor decreases until at one-half load the power factor of the two motors is very nearly the same. Many motors in actual service operate only a portion of the time at full load, and in cases of this kind the total reactive kv-a. of the line-start motor over a period of time is but little more than that which a standard squirrel-cage motor would require.

This equality in power factor at light loads is only true if the two motors have identical stators and therefor have the same magnetizing current. This latter condition is almost always true, however, between 5 and 30 hp., for four- and six-pole, 60-cycle motors.

The efficiency of the normal-torque high-reactance motor is the same as that of the standard squirrel-cage motor. Since its power factor is lower than that of the standard motor, the stator copper loss must be slightly higher, but this additional loss can be counterbalanced by decreasing by a small amount the running resistance of the rotor.

High-Torque High-Resistance Motors

The high-torque high-reactance motor is the line-start motor of the high-reactance type designed for application to loads requiring a higher starting torque than that developed by the normal-torque line-start motor. It has 250 per cent starting torque as compared with 150 per cent for the normal-torque motor.

The rotor resistance at standstill of the high-torque motor must therefore be 167 per cent of that of the normal-torque motor. In order to keep the maximum torque above 200 per cent it is necessary in the high-torque motor to have the slip at full load higher than in the normal-torque motor. This distinction may be seen in Fig. 1.

It follows that the efficiency of the high-torque motor is lower than that of the normal-torque motor. This difference is from 1 per cent to 2 per cent at full load in sizes from 5 hp. to 30 hp.

The high-torque motor also has a lower power factor than the normal-torque motor.

The running characteristics of the high-torque motor are consistently inferior to those of the normal-torque motor. It is therefore to the purchaser's advantage

to use this motor only in cases which actually require the high torque developed.

Normal-Torque High-Resistance Motors

The high resistance type of motor is distinguished from the high reactance type by the fact that in the former there is no eddy-current effect introduced in the rotor at standstill.

Limitation of starting current is obtained by either reducing the total magnetic flux per pole or increasing the horsepower rating of the frame in question.

The required starting torque is obtained by increasing the rotor resistance and since eddy-current effects are not used, the rotor resistance is not altered in going from standstill to full speed. This type of motor has therefore an inherently high slip and low efficiency at full load. The speed–torque curve of such a motor shown in Fig. 6 indicates a motor very similar to those special

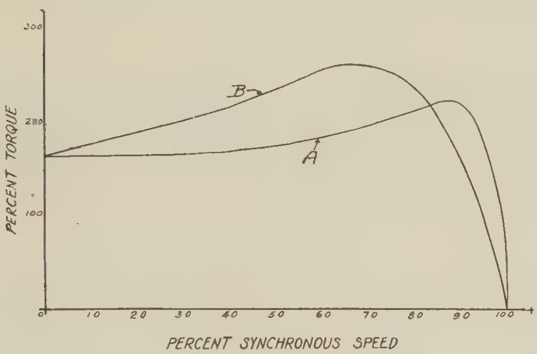

Fig. 6

a. Torque curve—Normal-torque high-reactance motor
b. Torque curve—Normal-torque high-resistance motor

high-slip motors designed for driving punch presses and other flywheel loads.

The high resistance type of motor has an advantage in that the full-load power factor is quite high but the full-load efficiency is correspondingly low and becomes rapidly lower at overloads.

The low efficiency of the high resistance type of motor indicates that this motor will operate at a higher temperature rise than a motor of the high reactance type.

The average accelerating torque is higher than that of a high reactance type motor having the same starting torque as shown in Fig. 6, where torque curves of the two types are superimposed.

Testing of Line-Start Motors

The testing of line-start induction motors and the subsequent use of these tests in preparing trustworthy guarantees necessitates precautions not necessary in the testing of standard squirrel-cage motors.

In preparing guarantees for standard squirrel-cage motors, it is common practise to compute the power factor and the conventional efficiency from data obtained from running light and blocked rotor tests. The computation may be done by the use of either the exact equivalent circuit or the circle diagram.

In preparing guarantees for line-start motors of the high-reactance type, however, the leakage reactance obtained from the blocked rotor test is not suitable for use in calculations at full load. It is too low by the amount of the incremental reactance, and power factor guarantees computed from it will be higher than the values actually realized in the motor.

Power factor guarantees of line-start motors should, therefore, be based primarily on carefully conducted wattmeter tests with the motor connected to a dynamometer.

An alternative method of arriving at the power factor consists in calculating the incremental reactance and adding it to the test value of standstill reactance in order to obtain the value of running reactance needed in the equivalent circuit or circle diagram. This method should be considered acceptable only when the individual designer has perfected the technique of calculating the incremental reactance to the point where wattmeter tests can be consistently checked by calculation.

Next to an interest in trustworthy power factor and efficiency guarantees, the purchaser of a line-start motor should be particularly interested in how the starting current is measured. If the starting current is extrapolated from a measurement made at a reduced voltage, the published value of the starting current may be from 10 per cent to 15 per cent lower than the actual starting current taken by the motor when connected to the lines. Any misunderstanding over this point could be avoided by a uniform practise among motor manufacturers of guaranteeing starting current values actually measured at full voltage.

A FRUITFUL INSTITUTE MEETING

Another winter convention of the American Institute of Electrical Engineers has passed and left a record of splendid engineering papers and discussions. This meeting has come to mark the annual peak of technical developments in the electrical art, and more than two thousand engineers are brought together by its meritorious program.

* * * *

The Institute is doing splendid work, and the engineers find in its fold a welcome rallying place. It must not be forgotten that facts are difficult to find in this changing world and that the greatest stimulus to research and development often comes through personal pride of opinion. Engineers are strong individualists. The dynamic urge that leads them into controversies to support their opinions is a symptom of the force that makes them productive. Debates and discussions stimulate development, and the record of the winter convention last week contains very many "behind the scenes" ideas and personal opinions that will be productive of much that is new in the coming years.—*Electrical World.*

The Cincinnati Regional Meeting

Both instruction and entertainment are offered in the Regional Meeting of the A. I. E. E. to be held in Cincinnati, March 20-23 with headquarters at the Hotel Gibson. Noteworthy technical sessions, inspection trips, a student session and Branch conferences and a dinner with some notable speakers are the main events of the program.

Technical Sessions

Timeliness and variety distinguish the technical papers to be presented. Four sessions are arranged and they will include such subjects as power stations, transmission, distribution, mercury rectifiers, generators, railway power economics, welding of buildings and machines, steel rolling, high-speed instruments, current transformers, illumination of airports, telephone construction, etc. The accompanying program gives the titles of the papers.

Student Meetings

A session on Student Branch activities will be held Thursday morning, March 21. All members are invited to attend this student session. Luncheons of Branch Counselors and Chairmen will be held March 20 and 21.

Inspection Trips

Trips to several points of engineering interest are planned as shown below.

Details on these trips as well as the cost of each may be obtained at the registration desk.

THURSDAY

8:30 a. m. and 9:30 a. m. All day trips to U. S. Experimental Stations, Wright Field, Dayton, Ohio

FRIDAY

1:30 p. m. Two trips to plants of Union Gas and Electric Co. and Cincinnati Street Railway Co.

1:30 p. m. Trip to Andrews Steel Company, Newport, Kentucky

SATURDAY

8:45 a. m. Trip to Crosley Radio Corp. transmitting station, Mason, Ohio

8:45 a. m. Trip to Champion Coated Paper Co., Hamilton, Ohio.

In addition to these inspection trips an airplane trip over Cincinnati may be taken at 4:00 p. m. each day.

Dinner

The convention Dinner will be held at the Hotel Gibson at 7:00 p. m., March 21. At this dinner it is planned to have addresses by R. F. Schuchardt, President of the Institute, and other well known speakers.

Ladies' Entertainment

Special plans have been made for the entertainment of ladies. The schedule of ladies' events is shown elsewhere in the anouncement.

Reduced Railroad Rates

Reduced railroad rates under the certificate plan will be available to those who attend the meeting. Under this plan each person who travels by train to Cincinnati should obtain a certificate from his local ticket agent when purchasing his ticket to Cincinnati. The certificate must be deposited at the registration desk for validation. If 150 certificates are deposited they will be validated and returned to their owners who will then be entitled to obtain return tickets at one-half the regular rates, provided the return route is the same as the route used in coming to Cincinnati.

Local ticket agents should be consulted regarding the dates on which certificates may be obtained and used.

Everyone should get a certificate with his ticket to Cincinnati. Even if he does not intend to use it, the certificate will help others get the reduction in fare, which may amount to considerable saving for those coming from distant places.

Register in Advance

By registering in advance by mail, members will help the local committees in making plans.

At the meeting a registration fee of one dollar will be charged. Students will be exempt from this fee.

Hotel Reservations

Those desiring hotel reservations should communicate in advance with the hotel management. Reduced rates for those attending the meeting have been offered by the Hotel Gibson. These rates are $3.00 and up for single rooms and $5.00 and up for double rooms, all rooms having bath.

City Transportation

Posters will be located in the various depots giving information concerning street car routes. The Eureka Auto Storage Company at 121 E. Third St. has been appointed official garage and will offer a special storage rate to members. Zumstein-Town Taxis are the official cabs.

Committees

The general committee which has charge of the Cincinnati meeting is as follows: J. L. Beaver, chairman (Vice-President District No. 2); R. C. Fryer, Vice-Chairman; Raymond Bailey, Secretary; W. E. Beatty, F. C. Caldwell, F. S. Dewey, L. O. Dorfman, R. C. Faught, E. S. Fields, R. T. Greer, L. J. Gregory, H. D. Rei, L. G. Smith, H. L. Swift, A. M. Wilson and R. Woodward.

PROGRAM

(All sessions will be held in Ballroom of Hotel Gibson)

WEDNESDAY

9:00 A. M.

Registration

10: A. M.

Address J. L. Beaver, Vice-President Middle Eastern District A. I. E. E.

Address, Hon. Murray Seasongood, Mayor, City of Cincinnati

Address, R. F. Schuchardt, President, A. I. E. E.

10:30 A. M.

General Session

1. *Recent Developments in Telephone Construction Practises*, B. S. Wagner and A. C. Burroway, Cincinnati & Suburban Bell Tel. Co.
2. *Illumination of Airports and Airways*, H. E. Mahan, General Electric Co.
3. *Iron Losses in Turbine Generators*, C. M. Laffoon and J. E. Calvert, Westinghouse Elec. & Mfg. Co.

12:30 P. M.

Luncheon Meeting. Branch Counselors and Branch Chairmen.

2:00 P. M.

Automatic Stations and Welding Session

4. *Street-Railway Power Economics*, J. A. Noertker, Cincinnati Street Railway Co.

5. *Automatic Mercury-Arc Rectifier Substations in Chicago*, A. M. Garrett, Commonwealth Edison Co.
6. *Arc Welding of Steel Buildings and Bridges*, F. P. McKibben, General Electric Co.
7. *Fabrication of Large Rotating Machinery*, H. V. Putman, Westinghouse Elec. & Mfg. Co.
8. *Electrical Equipment for Continuous Bar, Plate and Hot Strip Mills*, J. B. Ink, Dwight P. Robinson Co.

Thursday

10:00 a. m.

Student Activity Session

The Student Branch as a part of the Institute Organization, H. H. Henline, Assistant National Secretary, A. I. E. E.

The Student Convention, Its Purposes and Procedure, Moreland King, Counselor, Lafayette College

Report on the Work of the Student Branches, L. A. Doggett, Counselor, Pennsylvania State College

Notable Features of Branch Work, By Student Chairman. A series of two-minute reports. A prize of $10.00 will be awarded for the best report.

12:30 p. m.

Luncheon Meeting. Branch Counselors and Branch Chairmen

2:00 p. m.

High Speed Instruments and Measurements Session

9. *High-Speed Photography in Electrical Engineering*, H. W. Tenney, Westinghouse Elec. & Mfg. Co.
10. *Oscillographs for Recording Transient Phenomena*, W. A. Marrison, Bell Telephone Laboratories
11. *A New Type of Hot-Cathode Oscillograph*, R. E. George, Purdue University
12. *Bushing-Type Current Transformers for Metering*, A. Boyajian and W. F. Skeats, General Electric Co.
13. *Excitation of Current Transformers Under Transient Conditions*, D. E. Marshall and P. O. Langguth, Westinghouse Elec. & Mfg. Co.

7:00 p. m.

Regional Meeting Dinner

Friday

10:00 a. m.

Electric Power Systems Session

14. *Fused Arcing Horns and Grading Rings*, P. B. Stewart, Union Gas & Electric Co.
15. *Operating Experience with the Low-Voltage A-C. Network in Cincinnati*, F. E. Pinckard, Union Gas & Electric Co.
16. *Recent Additions to Generating Capacity on the System of the Columbia Gas & Electric Corporation*, E. S. Fields, Columbia Engineering and Management Corp.
17. *Investigation of Transmission Lines with Artificial Lightning*, K. B. McEachron, General Electric Co.

1:30 p. m. Inspection Trips

Saturday

8:45 a. m. Inspection Trips

Ladies' Entertainment Program

Wednesday, March 20

9:00 a. m. Registration (Club Room A-10th Floor Hotel Gibson)
Informal Reception and Announcements
2:00 p. m. Theater

Thursday, March 21

10:00 a. m. Sight-seeing Trip
3:30 p. m. Card Party
7:00 p. m. Dinner

Friday, March 22

10:00 a. m. Shopping Parties or Sight-Seeing Trips
3:30 p. m. Card Party

Saturday, March 23

9:00 a. m. Inspection Trips

Dallas Regional Meeting May 7-9

Dallas, Texas, will be the location of the A. I. E. E. Regional Meeting to be held under the auspices of the South West District, May 7-9. A most attractive program is being arranged, including technical papers on the subjects of network distribution, automatic reclosing of circuits, bare-wire distribution, interconnection, lightning research, transformer behavior under lightning conditions, lighting of airways and flying fields, waterworks electrification, train signals, and telephony.

Two student sessions, inspection trips, and a dinner are other important features of the meeting.

More details of the program will be published in the April issue of the Journal.

The 1929 Summer Convention

An excellent technical program and a fine series of entertainment events are promised for the coming Summer Convention of the Institute, to be held at Swampscott, Mass., June 24-28.

The proposed technical sessions include papers on distribution, automatic stations, electric railways, shielding in electrical measurements, and electrical machinery. The annual report of the Institute's Technical Committees will also be presented, and these cover developments in all branches of electrical engineering.

Annual conference of Officers and Delegates will be held on the first day.

A most active and enthusiastic committee is working out details of the entertainment.

Further information will be published in later issues of the Journal.

Attendance Records Broken at Winter Convention

The Winter Convention held in New York, January 28 to February 1 has the distinction of being the largest Institute convention in the number attending the various events, and one of the most interesting, technically. The technical sessions were unusually well attended and the 42 papers brought forth a great amount of discussion. A summarized report of the discussion will be given in the April Journal and the complete report will be printed in the Transactions. About 2000 were present during the week, and attendance records were broken, for the inspection trips, the Smoker, and the Dinner-Dance.

Presentation of Edison Medal

One noteworthy event of the meeting was the Edison Medal presentation to Dr. F. B. Jewett in the Engineering Auditorium, on the evening of Wednesday, January 30. H. A. Kidder, Chairman of the 1929 Winter Convention Committee, was presiding officer. An account of this meeting will be found elsewhere in this issue.

Lecture by Dr. Howe

Immediately following the Edison Medal presentation on Wednesday evening, a lecture on "Electricity and Chemistry—Team Mates in Progress," was given by Dr. Harrison E. Howe, Editor of Industrial and Engineering Chemistry. Dr. Howe told in a most interesting way of many modern developments in useful materials, which have been achieved through research and the application of electricity and chemistry.

Inspection Trips

There were more than 1150 registrations for the trips of inspection to 18 places of interest. The demonstrations given

at the Bell Telephone Laboratories were the most popular, 600 attending this exhibition on Wednesday afternoon. Hell Gate Station, the Electrical Testing Laboratories, and picture transmission at a plant of the American Telephone & Telegraph Company, were next in order of popularity, though every trip had a share of attendance.

Entertainment

The Smoker and the Dinner-Dance had attendances of respectively 825 and 800, which exceed the attendance, of any previous year. Both these events proved thoroughly enjoyable.

Ladies' Entertainment

For the first time at a Winter Convention, a Ladies Committee was in operation, and the innovation was a decided success. Various trips, shopping tours, teas, etc., were arranged for their pleasure and convenience.

Committees

The excellent organization and work of the committees which had charge of the various parts of the program are worthy of highest mention. The outstanding success of the convention reflects well deserved credit on all members of these committees.

Edison Medal Presentation

The ceremony of presentation of the Edison Medal to Dr. F. B. Jewett during the Winter Convention, took place on Wednesday Evening, January 30, in the Engineering Auditorium. The meeting was called to order by Vice-President H. A. Kidder, Chairman of the Convention Committee, who occupied the chair.

The first speaker of the evening was John W. Lieb, member of the Edison Medal Committee and Past-president of the Institute. Mr. Lieb spoke briefly of the history and underlying purposes of the Edison Medal, which through its award affords individual recognition and appreciation by the electrical industry of distinguished achievement in electrical science.

Following this, General John J. Carty, also an Edison Medalist, related some of Dr. Jewett's contributions to the art of electrical communication, for which he was awarded the medal. An outline of Dr. Jewett's career has been published in the Journal for January, 1929.

The medal was then presented to Dr. Jewett by Senior Vice-president O. J. Ferguson, acting in behalf of President Schuchardt who was absent.

Dr. Jewett responded with a short address in which he said in part as follows:

Edison Medal Response

The twenty-five years of my active participation in the development of electrical communication are practically the extent of the period in which engineering has been influenced largely by a direct, potent and conscious application of the methods and knowledge of research as they exist in the socalled pure science fields. The dawn of this era found telephony in the United States particularly happily conditioned to benefit from what was in store. Hospitable to the engineer from the beginning, its development at that time was largely his work. Far-seeing men of engineering training or experience, the leader of whom was J. J. Carty, were in commanding positions. They had the vision to see that the problems ahead demanded a mode of attack and, to an extent, a personnel different from anything theretofore applied.

Fortunately for the ultimate success of their plan to solve problems by new knowledge applied in new ways, the fundamental business structure of the Bell System is ideal.

* * *

A quarter of a century ago the telegraph art the world over was in a sort of Korean ancester worship state, where no man could hope to accomplish as much as those who had preceded him. Fortunately time has long since removed this inhibition. Success of the research method when applied to telephone problems not only rekindled imagination about telegraph problems, but in many cases rather automatically provided the answer to questions in the technically simpler field. The result is today an almost wholly new telegraphy.

If, in addition to accomplishments in its own proper field, more than rejuvenation of a moribund art is needed to prove the power inherent in industrial research as developed in the field of telephony, one has but to turn to the opposite pole. Radio, with all its spectacular ramifications of recent years, was still in swaddling clothes for nearly half the period we are here interested in. The time of its great development came when the methods and many of the tools which had proven so effective in wire telephony were applied to it. Even that wonderful thing, the electron tube, made originally to meet a radio need, and without which the present-day art could not exist, had to visit the research laboratory, change its characteristics and become a useful tool of wire telephony before it could develop into the marvelous device we know today.

Or, going farther afield, witness the impress of communication research methods and results on the phonographic and motion picture arts.

Internally the seed of that modern research organization implanted in the Bell System grew apace. It expanded mightily in size as the years passed. Even more, it expanded in the scope of its activities and the distance back toward truly fundamental knowledge it found it expedient and profitable to go. Originally adjunct to an engineering department, it rapidly absorbed many of the more fundamental engineering functions. From being in its early days a thing external to the main scheme of organization, it has come now to be the very center of everything physical in the telephone business. So effective has the machine of the Bell System research and development organization become that questions of doubt are seldom, if ever, raised against its statements that this or that can be accomplished. The question is merely, how soon can the thing be done and what is involved? Possibly it is in tribute to a record of striking achievement that doubt is expressed only when the research people say something probably cannot be done!

Except for the fact that its operations in modern industrial research were early begun, and the further fact that their present magnitude is very great, what has gone on these past two decades in the Bell System is not different in kind from what has gone on in many other fields of applied science. The initial skepticism; the transient antagonisms; the changing point of view about fundamental investigation; rapid growth and an alteration in the whole scheme of organization values, are a common phenomena whereever industrial research, as we now understand it, has been tried out and persisted in.

That this newest of industry's major tools has come to stay, and in many directions to grow in importance, is quite certain. What is not so clear is how the numerous internal and external problems which are arising out of these new groupings of highly trained scientists and engineers are to be worked out.

In its external relationships, that is, its relationships to other groups in the corporate organization, it is evident that in addition to the numerous routine functional contacts of the reseach group, its director of research must be capable of taking, and actually take a real part in the management of the business. If he is not this sort of man someone outside the research and development group will be in fact the real director of research. Whether these groups of highly trained scientific men can always develop from their own ranks individuals capable of and willing to assume the type of problems which fall to the lot of the operating executive is of course a question.

Personally I believe it can be done in most cases, and a life of intimate association with industrial research has left me strongly of the opinion that every effort should be made to find the real executive leaders in the research group itself. The difficulty which confronts the executive who has not himself gone through the mill is the difficulty of appraising properly those factors which at some stages of any complex problem can be valued only by the man who is himself trained and experienced.

The executive developed from the research laboratory may have unorthodox views about many business and policy matters. His own self-esteem may be hurt by the mildly indulgent condescension of fellow executives who admit that they are practical men. This makes very little difference to the business or to the research director himself, if these fellow executives as well as his subordinates respect him in his own field. What does matter to the business and to the efficiency of the research department is whether the producers in that organization feel that they have an understanding leader or merely a so-called good executive who is quite likely on occasion to confuse centimeters with kilograms.

The research men can be trusted to organize their own work most effectively. Where the efficient leader is necessary is in interpreting their work to the non-technical part of the management, and conversely, in translating business needs or limitations into terms of research values. We who were in the van in industrial research have attained to these connecting positions almost automatically In the time ahead conscious attention to the problem of leadership should produce better results than any thus far attained. The success of the industrial research organization, which to a large extent is determined by its leadership, is a thing which no progressive technical industry can afford to slight. Present tendencies would seem to indicate that many of the industrial leaders of the future must come from the ranks of the industrial scientists. This appears to be so, because in many instances these men alone have the knowledge which permits them to look into the future with a certainty not permitted to others.

In twenty-five years we have learned a lot. We have learned that an enormously valuable science can be conducted under the rules which govern

business as well as under the rules which govern institutions of learning. We have learned that men of the highest scientific training and with great creative imagination can, in a suitable environment, work productively in cooperation with others under the conditions imposed by industry. But we have learned also that the effective research laboratory is a sensitive machine. It is likely to be turned overnight into a mere experimental shop by something which affects simply men's peace of mind. The motions of productivity are still there but the real values have vanished. These real values are the concrete end results of an organized and orderly attempt to direct creative imagination along generally defined lines. If industrial research is to continue to pay large dividends, those responsible for it must be wise both in the ways of science and engineering and also in the ways of sensitive men.

I surmise that there is little to fear for the future, however. Too much has already been accomplished; too fine a technique has been developed, and the field of the still unknown which challenges the attention of able men is too alluring to make plausible any supposition of substantial backsliding. Blunders will doubtless be made, some even a repetition of those we have ourselves made, but if a kindly Fate permits us of the pioneer era to live out the allotted span of life, I think we will find ourselves admitting that the younger generation is building marvelously on the foundation some of us helped to lay.

AMERICAN ENGINEERING COUNCIL

HEARING ON HYDRAULIC LABORATORY BILL

The hearings on the National Hydraulic Laboratory Bill, S.1710 were reopened January 28, at which time Col. E. M. Markham, who has recently returned from a three months inspection trip of European hydraulic laboratories, testified that he believed that any experimental work along the lines of rivers and harbors should be under the control and supervision of the engineer in charge of the work.

Mr. A. W. Berresford, President of American Engineering Council, followed Colonel Markham, pointing out that a research man is rarely a good field man or engineer and to place research work under the control and supervision of a field man is contrary to all precedent in industry or engineering. He gave a long list of prominent engineers who have endorsed this bill and named forty engineering organizations which have taken definite action concerning it. Doctor George K. Burgess testified in behalf of the bill and gave a long list of problems which the Bureau of Standards had solved in other lines of work for the Army engineers to the harmonious satisfaction of all concerned. He stated that he was unusually fortunate in having on his staff at present, two men exceptionally qualified to undertake work in a national hydraulic laboratory. Colonel George Pillsbury, of the Corps of Engineers, described for the committee a model experiment which he has recently performed in connection with work on the Delaware River. He stated that the dredging to maintain the proper depth of this river was now costing approximately $2,000,000, that when he took over this work, there were four or five plans proposed for the construction of a dike which would divert the water of the river and eliminate a large portion of this dredging; perhaps $365,000 per year would be saved. He stated that his thirty years of river and harbor experience had been of great assistance in planning the model tests which had cost approximately $5000. He also testified that the plans for which he had a preference did not prove most satisfactory when the model studies were made, and were not the ones which he, after conducting the model studies, recommended to the Chief of Engineers. General Taylor, former Chief of Engineers, U. S. A., also testified, recounting at great length the accomplishments of the Corps of Engineers and calling attention to the superiority of its construction work over that used in many places in Europe. He closed his testimony by stating that he did not believe a laboratory in the Bureau of Standards would be objectionable, provided the bill was so worded that such a laboratory could not undertake the study of problems with which various governmental agencies were concerned, unless specifically requested to do so. He proposed an amendment to that effect. Mr. N. C. Grover, of the U. S. Geological Survey, testified that the hydraulic laboratory under the Bureau of Standards would be of great service to his department, and that there was not at present in the United States a laboratory satisfactorily equipped to undertake the studies in which his department was interested. Mr. L. A. Jones of the Bureau of Public Roads, testified that the Department of Agriculture would find continual use for a National Hydraulic Laboratory. Perhaps the outstanding testimony in favor of the hydraulic laboratory bill was presented by Mr. C. A. Bissell, Chief Engineer, Reclamation Service, who presented a list of over 100 problems of his department which might be studied in a national hydraulic research laboratory. He testified that the Bureau of Reclamation could keep the laboratory constantly busy for at least three years, and that in connection with studies upon the proposed Boulder Canyon Dam project alone the laboratory would pay for itself many times over.

CRUISER BILL PASSES SENATE

Engineers and contractors interested in shipbuilding were pleased with the passage on February 6 of House of Representative Bill 11526, which provides for the construction of fifteen new 10,000-ton cruisers. This bill passed the Senate with the same provision known as the "time clause" which had been inserted in the House. It provides that construction be started on five ships every three years. The provision was opposed by President Coolidge as, for budgetary reasons, he wanted the time of construction left to the discretion of the President.

GOVERNMENT EMPLOYEES COMPENSATION BILLS

It is frequently the case that matters which on the face have little to do with technical and engineering affairs, are far-reaching in their effect upon the engineering profession. This is true of the compensation bills which are now pending in Congress.

The Welch bill which became a law last year gave very substantial salary increases to the higher class of professional and technical employees of the government, but due to a decision rendered by the Comptroller General Mr. McCarl, the lower class of employees did not benefit so much. This has produced a storm of protest. Most experts on the intricate and involved question believe, however, that the decision was in perfect accord with the language of the bill as passed by Congress. There have been numerous efforts made to remedy this situation and two bills are before Congress at present, one known as the Lehlbach Bill, H. R. 16643, which would give to the Personnel Classification Board very large powers in promoting and increasing the pay, or demoting and decreasing the pay of employees, over the objection of the head of a given department concerned.

The Lehlbach Bill has been reported out favorably by the House Committee and he has requested the Rules Committee to grant a special rule under which to consider the bill so that it may come up in the House at an early date.

Most engineers and highly skilled and trained professional men in the government service are opposed to this bill as it is now written. The Brookhart Bill S.5148 provides for an increase in pay for the lower positions but definitely stipulates that no salary will be reduced, nor does it give any unusual powers to the Personnel Classification Board. This bill is apparently opposed by the Administration because of the large additional amount of money which would be required to comply with it.

Standards

Revision of "Illuminating Engineering Nomenclature and Photometric Standards"

The Illuminating Engineering Society, sponsor under the American Standards Association for "Illuminating Engineering Nomenclature and Photometric Standards," Section 37 of A. I. E. E. Standards and also an American Standard, is proposing to submit a revision of this standard which will be submitted under the proprietary method of the A. S. A. The present A. I. E. E. Standard 37 was developed by a committee of the

Illuminating Engineering Society and adopted by the Institute with the approval of the I. E. S.

STREET TRAFFIC SIGNS, SIGNALS AND MARKINGS

A report of a committee of American Engineering Council on "Street Traffic Signs, Signals and Markings" has just become available in pamphlet form. This report was developed as the result of a national survey of existing conditions made under the auspices of American Engineering Council. At the National Conference on Street and Highway Safety it was shown that a valuable service could be rendered by such a work and American Engineering Council agreed to undertake the work. The committee maintained the closest contact with all agencies affected and was eventually enlarged to become a Sectional Committee of the American Standards Association. The Standards Committee of the A. I. E. E. had a representative on the committee, Mr. W. T. Dempsey of the New York Edison Company.

The report is divided into two parts. Part I covers "Recommended Practise" and is divided into four sections, as follows: 1. Street Traffic Signs. 2. Street Traffic Control Signals. 3. Street Traffic Markings. 4. Safety Zones. Part II deals with "Facts and Experience" and gives illustrations in color and to scale for the various signs recommended. An Appendix to the report gives "Specifications for Sign Materials." Copies of the report may be obtained at a cost of 25 cents by writing to American Engineering Council, 26 Jackson Place, Washington, D. C.

STANDARD FOR FOUR-PIN VACUUM TUBE BASES RECOMMENDED

The Sectional Committee on Radio under the sponsorship of the A. I. E. E. and the I. R. E., has approved the report on a "Standard for Four-Pin Vacuum Tube Bases" developed by one of its subcommittees. This report is now up for approval by the two sponsors previous to its submission to the American Standard Association for approval as American standard.

A. I. E. E. Directors Meeting

The regular meeting of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Wednesday, January 30, 1929.

There were present: Vice-Presidents O. J. Ferguson, Lincoln, Neb., J. L. Beaver, Bethlehem, Pa.; A. B. Cooper, Toronto, Ont.; C. O. Bickelhaupt, Atlanta, Ga.; E. B. Merriam, Schenectady, N. Y.; H. A. Kidder, New York, N. Y.; W. T. Ryan, Minneapolis, Minn.; B. D. Hull, Dallas, Tex.; Directors E. C. Stone, Pittsburgh, Pa.; C. E. Stephens, New York, N. Y.; H. C. Don Carlos, Toronto, Ont.; F. C. Hanker, East Pittsburgh, Pa.; E. B. Meyer, Newark, N. J.; J. Allen Johnson, Niagara Falls, N. Y.; A. M. MacCutcheon, Cleveland, Ohio; A. E. Bettis, Kansas City, Mo.; National Secretary F. L. Hutchinson, New York, N. Y.

In the absence of President Schuchardt, Senior Vice-President Ferguson presided.

A motion was adopted expressing the Board's sympathy to President Schuchardt in the recent death of Mrs. Schuchardt.

The minutes of the Directors' meeting of December 7, 1928, were approved.

Reports were presented of meetings of the Board of Examiners held December 19 and January 16, and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners the following actions were taken: 372 Students were enrolled; 297 applicants were elected to the grade of Associate; 12 applicants were elected to the grade of Member; two applicants were elected to the grade of Fellow; 39 were transferred to the grade of Member and eight to the grade of Fellow.

Among the Associates elected was Mr. L. V. Berkner, radio expert with the Byrd Antartic Expedition, and arrangements were subsequently made to notifiy him of his election by radio, through the *New York Times*.

Approval by the Finance Committee for payment, of monthly bills amounting to $22,355.13, was ratified.

Upon the recommendation of the Committee on Coordination of Institute Activities, the following schedule of meetings for the year 1930 was adopted:

Winter Convention..........	New York City—Last week in January.
Regional Meeting (Dist. No. 1)	Springfield, Mass.—May.
Summer Convention.........	Toronto, Ont.—Last week in June.
Pacific Coast Convention....	(location and date to be decided by the Pacific Coast representatives later; the meeting will probably be held in the North West).
Regional Meeting (Dist. No. 2)	Philadelphia—October.
Regional Meeting (Dist. No. 4)	Louisville, Ky.—November.

Upon the recommendation of the Standards Committee, approval was given to the Code for Protection Against Lightning, which had been developed under sectional committee procedure, with the Institute as one of the sponsors, for transmission to the American Standards Association, with the understanding that the Code is to be published by the Bureau of Standards.

Resolutions were adopted, as recommended by the Coordination Committee, that "traveling expenses at the usual rate be allowed for an alternate to represent each Section chairman or secretary who finds it impossible to attend a District Executive Committee meeting, such alternates to be chosen by the executive committees of the Sections," and that "traveling expenses be authorized at the usual rate for an alternate to represent any Branch chairman who is unable to attend a District Conference on Student Activities, such alternates to be chosen by the executive committee of the Branch with the approval of the Counselor."

Upon request of the officers of the Houston Section, which had received the approval of the chairmen of the Sections and Finance Committees, the Board authorized the extension of the territory of that Section to include thirty-six additional counties.

The appointment of the Institute's two representatives on the Council of the American Association for the Advancement of Science for the calendar year 1929, was referred to the President with power.

Other matters were discussed, reference to which may be found in this and future issues of the JOURNAL.

UNITED ENGINEERING SOCIETY

ANNUAL REPORT

The Board of Trustees (three from each of four societies) conducts the business committed to United Engineering Society by its Founder Societies under its charter, the Founder's Agreement and the Library Agreement.

A draft of a budget of revenue and expenditures for the ensuing calendar year is presented each September to the Secretaries of the Founder Societies for information and comment. Each January, reports for the preceding calendar year, by the President, the Treasurer, and the Finance Committee, and a financial statement of receipts and expenditures are sent to the office of each Founder Society. Reports are made also by Engineering Societies Library and Engineering Foundation.

Engineering Societies Building is tax exempt. It is administered in the main on a cooperative basis and not for profit. For convenience, and with the aid of experience, assessments for the use of offices have been reduced to the form of rentals and those for use of the meeting halls to a schedule of charges. Offices not used by the Founder Societies and their joint organizations are allotted to Associate Societies. When the meeting halls are not in use by the Founder Societies, other patrons use them to the extent of the demand which it has been practicable to develop. Revenue from Associate Societies and from meeting

halls reduces the burden upon the Founder Societies for maintenance, operation, and fixed charges on the building. To each Founder Society, interest at the rate of 4.8 per cent per annum is paid on its investment of $262,500 in the land and building, amounting to $12,600 a year. The building is maintained constantly in good condition and there is a Depreciation and Renewal Fund, a long-range budget provision against major repairs and renewals and the obsolescence of the structure above the foundations. Since it was dedicated in 1907, additions and improvements have been made to the building from time to time, the largest being that of three stories in 1916-17, when the Civil Engineers joined United Engineering Society.

United Engineering Society also administers several trust funds for Engineering Foundation and Engineering Societies Library, and it is seeking a much needed increase of these endowments. In financial operations and management of the property, the Trustees have the services of trust companies as custodians for the funds and advisers in making investments, legal counsel, certified public accountants as auditors, and a consulting architect.

Following is an extract of the Annual Report of the Treasurer of the United Engineering Society for the year 1928:

SUMMARY

Operation of Building

Credit Balance January 1, 1928		$ 7,331.35
Insurance Refund and Adjustments		2,253.90
Building Revenue 1928	$ 130,551.72	
Building Expenditures 1928	111,767.59	18,784.13
		$ 28,369.38
Annual Payment to Dep. & Renewal Fund		$ 12,000.00
Credit Balance December 31, 1928		$ 16,369.38

Operation of Library

Maintenance Revenue	$ 46,009.65	
Maintenance Expenditures	45,584.10	
Credit Balance Dec. 31, 1928		$ 425.55
Service Bureau Revenue	$ 20,261.47	
Service Bureau Expenditures & Adjustments	19,163.80	
Credit Balance Dec. 31, 1928	$ 1,097.67	
Credit Balance Jan. 1, 1928	2,830.19	
Total Credit Balance December 31, 1928		$ 3,927.86

Funds and Property

Funds held by U. E. S. Dec. 31, 1928 (book value)	
Depreciation and Renewal	$ 233,743.73
General Reserve	5,773.40
Engineering Foundation	517,753.95
Henry R. Towne Engineering	49,953.13
Library Endowment	104,652.22
Reserve for Depreciation of Capital of Library	4,000.00
Edward Dean Adams	100,000.00
John Fritz Medal (U. E. S. Custodian)	3,500.00
Louvain Memorial Fund (cash in bank)	9,470.51
Total	$1,028,846.94
Real Estate owned by U. E. S., cost to Dec. 31, 1928	1,973,410.42
Operating cash and petty cash	14,251.47
Accounts Receivable	2,032.96
Value of Library (as appraised for insurance)	348,056.00
Winchell Library Suspense Account	374.35
Unexpired Fire Insurance Premiums	6,340.55
Total Property for which U. E. S. is Trustee or Custodian	$3,373,312.69

BALANCE SHEET

Assets

Real Estate		
Land	$ 540,000.00	
Building	1,376,239.26	
Equipment	33,171.16	
Founders Preliminary Expenses	24,000.00	$1,973,410.42
Investment and Cash Uninvested		
Depreciation & Renewal Fund		233,743.73
General Reserve Fund		5,773.40
Engineering Foundation Fund		517,753.95
Henry R. Towne Engineering Fund		49,953.13
Library Endowment Fund		104,652.22
Reserve for Depreciation of Library Capital		4,000.00
Edward Dean Adams Fund		100,000.00
Louvain Memorial Fund—Cash in bank		9,470.51
Operating cash and petty cash		14,251.47
Accounts receivable		2,032.96
Winchell Library Suspense Account		374.35
Unexpired Fire Insurance Premiums		6,340.55
		$3,021,756.69

Liabilities

Founders' equity in property	$1,973,410.42
Depreciation & Renewal Fund	233,743.73
General Reserve Fund	5,773.40
Engineering Foundation Fund	517,753.95
Henry R. Towne Engineering Fund	49,953.13
Library Endowment Fund	104,652.22
Reserve for Depreciation of Library Capital	4,000.00
Edward Dean Adams Fund	100,000.00
Louvain Memorial Fund Balance	9,470.51
Endowment Committee Reserve—balance on hand	702.57
Endowment Contribution (undesignated)	1,000.00
Louvain Memorial Dinner—Cash on hand	225.00
Deposits on account of hall rentals	328.00
Deposits—Library Service Bureau	20.97
Credit balance in Activity Accounts	20,722.79
Total	$3,021,756.69

Twelfth Exposition of Chemical Industries

The Twelfth Exposition of Chemical Industries which will open at the Grand Central Palace, New York, N. Y., May 6th to 11th, bringing together thousands of chemists, chemical and research engineers, and manufacturers and buyers from forty odd industries is particularly significant of the advancement made in the chemical industries field during the last quarter of a century.

The various groups of this important industry as represented at the exposition will exhibit the most modern equipment and advanced practises of chemical engineering and chemistry. The Instruments of Precision group will have a number of exhibits, among which will be one for a spectro-photometer and hydrogenion colorimeter. These two will be of particular interest to the color and dye industry. The hydrogenion colorimeter is new and will be exhibited at the Exposition for the first time. A number of balances, microscopes, high-temperature furnaces and color analyzing apparatus will also be exhibited. A new method of connecting vitreosil pipe lines will be presented at the coming Exposition. The Students Course will be under the direct supervision of Dr. W. T. Read, Professor of Chemistry from Texas Technological College.

Cuban Engineers Extend Invitation

The Cuban Society of Engineers has adopted a resolution to extend to all members of the Institute who visit Havana the courtesy of the use of its building, which is located next to the Plaza Hotel and close to the hotel and shopping districts.

A considerable number of members of the Institute residing in Cuba are members of the Cuban Society, and the courtesy extended will afford a convenient opportunity for any members of the Institute visiting Cuba to meet Cuban Institute members, as well as other engineers.

Resistivity of Aluminum Investigated

A meeting was held at the Laboratoire Central d'Electricité, Paris, on November 16, 1928, to consider proposals for the values of the electrical and other qualities of aluminum for transmission lines and its recommendation to the International Electrotechnical Commission for adoption. Professor Paul Janet, Director of the Laboratoire Central d'Electricité, presided, and the following delegates were present: For France, M. R. Jouaust,

Laboratorie Central d'Electricité, M. De Biran, Aluminium Français, M. Lamberg, Tréfileries de Rai-Tillières, M. Marquaux, Tréfileries du Havre; GERMANY, Herr Dr. Apt, Deutsche Gesellschaft für Metallkunde, Herr Prof. Dr. Von Steinwehr, Physikalisch-Technische Reichsanstalt, Herr Oberingenieur Wunder, representative of users; GERAT BRITAIN, Dr. E. H. Rayner, National Physical Laboratory, Mr. E. T. Painton, British Aluminium Co.; U. S. A., Dr. G. K. Burgess, Director, Bureau of Standards, Mr. W. C. Binz, Representative of the Aluminum Co. of America, Mr. Bassett, Representative of the Aluminum Co. of America, Dr. C. O. Mailloux, Representing U. S. National Committee of I. E. C.

The subject has been under consideration for some years, information having been interchanged on a large number of experimental determinations made at the chief national laboratories of the resistivity, density, and other qualities of both hard drawn and annealed material. It was considered that sufficient information of this nature had been obtained, and the subject had reached a stage when commercial interests were more particularly involved. The type of aluminum considered was restricted to hard drawn material in the form of wire, the annealed being left for consideration at a later date if it be thought desirable eventually to formulate standards for the softer material. The effect of annealing is considerable, usually resulting in a lowering of resistance of more than 1 per cent. It was decided that it was of first importance to prescribe an upper limit of resistivity with which all commercial supplies of aluminum should comply. The chief reason for considering this as being important is the fact that the presence of impurities, if they exceed about 0.5 per cent are liable appreciably to increase the tendency to corrosion. Since increase in impurity is accomplished by an increase of resistivity, a limit to the resistivity permissible acts sufficiently approximately as a limit to the risk of corrosion. It is also necessary to define "hard drawn" since resistivity increases with increased strength such as would be obtained by cold working, and in consequence resistivity standards must refer to a well-defined range of tensile strength. These matters and other physical characteristics necessary for specification purposes were agreed to on the following lines: The resistivity of commercial hard drawn aluminum wire at 20 deg. cent. is not to exceed 2.873 microhm centimeters. This is to apply to wire before being stranded into a cable. If the wire is tested after having been stranded, an increase of 1 per cent of the above value is permitted. The wire is required to withstand for one minute a stress of 16 kilograms per square millimeter (22,760 lb. per sq. in.). The density of aluminum is assumed to be 2.703 at 20 deg. cent. The temperature coefficient of lineal expansion is 23 by 10^{-6}. The temperature coefficient of resistance is 0.004.

It was considered desirable to adopt a definite nominal value for the resistance of commercial aluminum, which could be used in designing transmission lines. This would naturally be less than the maximum mentioned above. It was thought that this should be the average value of good material as at present manufactured. In order to obtain information on which such a value might be founded, it was decided to postpone a decision on the subject until after March 1929, and that in the meantime the countries interested should send the necessary information to the Central Office of the International Electrotechnical Commission.

Research Graduate Assistantships at University of Illinois

To assist in the conduct of engineering research and to extend and strengthen the field of its graduate work in engineering, the University of Illinois maintains fourteen Research Graduate Assistantships in the Engineering Experiment Station. Two other such assistantships have been established under the patronage of the Illinois Gas Association. These assistantships, for each of which there is an annual stipend of $600 and freedom from all fees except for matriculation and diploma, are open to graduates of approved American and foreign universities and technical schools who are prepared to undertake graduate study in engineering, physics, or applied chemistry. Appointment is made and must be accepted for two consecutive collegiate years of ten months each, when, if all requirements have been met, the degree of Master of Science will be conferred. Half of the time is required in connection with the work of the department to which he is assigned, the remainder being available for graduate study.

Nominations are made from applications received by the Director of the Station not later than the first day of April, based upon the character, scholastic attainments, and promise of success in the principal line of study or research to which the candidate proposes to devote himself. Preference is given applicants who have had some practical engineering experience following the completion of the undergraduate work.

Research work and graduate study may be undertaken in architecture, architectural engineering, ceramic engineering, chemistry, civil engineering, electrical engineering, mechanical engineering, mining engineering, municipal and sanitary engineering, physics, railway engineering, and theoretical and applied mechanics. Additional information may be obtained by addressing THE DIRECTOR, Engineering Experiment Station, University of Illinois, Urbana, Illinois.

Proceedings of the International Illumination Congress

Widespread interest has been aroused in the forthcoming publication of the *Proceedings* of the recent International Illumination Congress which was held at Saranac Inn, New York, in September 1928, and which attracted to its sessions lighting experts from all over the world. The *Proceedings* will include all papers, reports, and discussions presented at the Saranac meeting, as well as several addresses of importance which were delivered during the Toronto Convention of the Illuminating Engineering Society, which immediately preceded it.

It will present also the results of the studies of eminent European and American scientists in the field of illuminating engineering. Among the subjects treated were lighting of factories, schools, churches, streets and highways, homes and public buildings; lighting for aviation, motion picture production, athletics, decorative and floodlighting, as well as the uses of lighting as an aid to medical science; the discussion of various materials and equipment will also be included.

Distribution is being handled by the offices of the Illuminating Engineering Society, 29 West 39th Street, New York, N. Y. The price of ten dollars per volume with a 25 per cent discount on orders received before March 1st, the date when forms will be closed is being changed.

Columbia University Scholarships in Electrical Engineering

The governing bodies of Columbia University have placed at the disposal of the American Institute of Electrical Engineers each year, a scholarship in Electrical Engineering in the schools of Mines, Engineering, and Chemistry of Columbia University for each class. The scholarship pays $350. toward the annual tuition fees which vary from $340. to $360., according to the details of the course selected. Reappointment of the student to the scholarship for the completion of his course is conditioned upon the maintenance of a good standing in his work.

To be eligible for the scholarship, the candidate recommended will have to meet the regular admission requirements, in regard to which full information will be sent without charge upon application to the Secretary of the University or to the National Secretary of the Institute.

In a letter addressed to the National Secretary of the Institute,

an applicant for this scholarship should set forth his qualifications (age, place of birth, education, reference to any other activities, such as athletics or working way through college, references and photograph). A committee composed of Messrs. W. I. Slichter (chairman), Francis Blossom, and H. C. Carpenter will consider the applications and will notify the authorities of Columbia University of their selection of a candidate. The last day for filing of applications for the year 1929-30 will be June 1, 1929.

The course at the Columbia School of Mines, Engineering, and Chemistry is three years in length and is on a graduate basis. A candidate for admission must have had something of a general education, including considerable work in mathematics, physics and chemistry. Three years of preparatory work in a good college or scientific school should be sufficient, if special attention has been given to the three preparatory subjects mentioned. A college graduate with a Bachelor of Science degree in engineering can generally qualify to advantage. The candidate is admitted on the basis of his previous collegiate record, and without undergoing special examinations. Other qualifications being equal, members of Student Branches of the A. I. E. E. will be given preference.

The purpose of this advanced course is to produce a high type of engineer, trained in the humanities as well as in the fundamentals of his profession. It is hoped that enrolled students and others qualified will show a keen interest in this scholarship.

Alloys of Iron Research

Of interest to all the Founder Societies—in fact to all engineering societies and industry—is the research work on alloys of iron which is now being undertaken by Engineering Foundation in cooperation with the American Institute of Mining and Metallurgical Engineers. A prospectus designated as Bulletin No. 3 gives full information regarding the purpose and scope of this work and copies of this Bulletin will gladly be supplied to anyone applying to Alfred D. Flinn, Director, Engineering Societies Building, New York, N. Y.

PERSONAL MENTION

N. J. Neall, Consulting Engineer and Fellow of the Institute, with offices at 12 Pearl Street, Boston, has opened an office in New York City, at 100 Broadway.

T. S. Gildersleeve, formerly Engineer in Transmission and Substation Engineering Department of Public Service Electric & Gas Co., Newark, N. J. Has been made Sales Engineer of the Standard Underground Cable Co., New York, N. Y.

Edward T. Newton has resigned from the position of Assistant Electrical Engineer of the American Brass Company of Waterbury, Connecticut to accept an appointment as a Junior Examiner in the United States Patent Office, Washington, D. C.

Panfilo Trombetta has resigned from the Industrial Control Department of the General Electrical Company to take charge of the Research Department of the Allen-Bradley Company, Milwaukee, Wisconsin.

Harrison A. Martin, formerly Assistant Engineer of the Electric Bond & Share Company, New York, resigned upon his return from Colombia, S. A., to become Engineer of the Peoples Light & Power Company, New York, N. Y.

C. M. Garland, Consulting Engineer, Chicago, has incorporated with J. A. Scribbins, also of Chicago, under the company name of Garland & Scribbins. Mr. Garland will occupy the position of Director of Engineering in a department to include power heating and industrial installations.

R. W. Shoemaker is Superintendent of the Electrical Department of the Turlock Irrigation District and Consulting Electrical Engineer for the Imperial Irrigation District, andM. M. McIntire is Electrical Engineer for the Imperial Irrigation District.

The Imperial Irrigation District is contemplating the construction of a $2,100,000 hydroelectric generation and distribution system utilizing the existing drops in the irrigation canal system. This corrects item as published in the February issue.

Obituary

Leonard Waldo, one of America's foremost electrical and metallurgical consulting engineers, died at his home January 26 after a brief illness. He was born in Cincinnati on the 4th of May, 1853 and received his education and degrees at Marietta College and Harvard University. When he was twenty-one he was sent as assistant astronomer on the United States Transit of Venus expedition to Tasmania and was later connected with the astronomical observatories of both Yale and Harvard. During the World War, Doctor Waldo was consulting engineer on illuminants and shells for the War Department, and conducted extensive tests at Aberdeen Proving Grounds, Lakehurst. Recently he had been occupied in research work on atomic structure. He was a widely known microscopist, had received the medal of the Royal Society of Arts of London for his research work, was a member of the American Institute of Mining and Metallurgical Engineers, the Society of the Chemical Industry, the Iron and Steel Institute, the Microscopic Society, the Fatigue of Metals Committee of the National Research Council, and of the Engineers Club of New York. He became a member of the Institute in 1888.

Walter Denny Uptegraff, Chairman of the Board of Directors of the Union Switch & Signal Company and President of the Definance Paper Company of Niagara Falls, died suddenly February 17 at Niagara Falls. Mr. Uptegraff was born in Pittsburg 1865, and for fifty years was associated with the Westinghouse Air Brake Company holding many executive positions under the late George Westinghouse, for the various Westinghouse interests. He was a life member of the National Geographic Society of Washington, D. C., a member of the American Society of Mechanical Engineers, and of the Bankers Club. He became an Associate of the Institute in 1906.

Doctor Ir. C. Lely, Honorary Member and President of the Koninklijk Instituut van Ingenieurs, died at The Hague on January 22, 1929. He was one of the most prominent engineers and statesmen of his country and his name will be perpetuated by the execution of the Zuiderzee Scheme.

William L. Simpson, Electrical Engineer for the Postal Telegraph-Cable Company of Chicago, Illinois, died December 1928. Mr. Simpson was a native of Windsor, Missouri, and was self educated in connection with his technical work. In 1911 he was chosen Assistant Division Electrical Engineer of the Postal Telegraph Cable Company and six years later became Division Electrical Engineer for his company. He was a member of, and adviser to, General Rules Committees of several states, governing construction, operation and maintenance of supply and signal lines; a member of the various Joint Committees on Electrolysis and committees on Interference Between Supply and Signal Lines,; was co-inventor of automatic railway signal systems and developed an improved phantoplex telegraphy system. Mr. Simpson was elected an Associate of the Institute in 1920 and was transferred to the grade of Member in 1926.

Thomas Duncan, President of the Duncan Electric Manufacturing Company and an electrical engineer of recognized ability, died at Los Angeles January 21, 1929. Born at Girvan, Ayrshire, Scotland, December 26, 1865, his name has been identified with the invention and manufacture of some of the best forms of recording electric meters and upwards of 100 patents. Among these were the method of protecting the accuracy of integrating wattmeters by shielding their damping magnets, a series transformer for use in connection with indicating, recording, and integrating apparatus, an automatic discount meter for allowing any predetermined discount during periods when the current consumption of the customer exceed a pre-

determined amount, an automatic discount meter which varies the discount during the month in accordance with predetermined amounts of consumption, several multi-rate meters operated from a central point, a line of storage battery meters which automatically compensate for the inefficiency of the cells during discharge so that they could not be injured by over-discharge, and many other devices of outstanding value to the profession, the Duncan meter alone being enough to assure him a place of prominence among his fellow engineers. Mr. Duncan joined the Institute as an Associate in 1894 and was transferred to the grade of Member in 1909.

DEATH OF MRS. BERRESFORD

Mr. A. W. Berresford, Past-President of the Institute and President of the American Engineering Council, is the recipient of the sympathy of his many friends in the profession in the loss of his wife on Sunday, February 10. Mrs. Berresford had suffered ill health for the past several months.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York.

All members are urged to notify the Institute Headquarters promptly of any changes in mailing or business address, thus relieving the members of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

A. Accarion, 2512 S. Massey St., Philadelphia, Pa.
Ernest K. Brown, 746 Bryson St., Youngstown, Ohio.
J. E. Cowart, 255 74th St., Brooklyn, N. Y.
L. M. Gamble, 1828 Decatur St., Brooklyn, N. Y.
Harry M. Hope, 274 Muirfield Rd., Los Angeles, Calif.
Oscar Kalley, 12 Memphis Ave., Floral Park, N. Y.
John Keefer, 484 Frederick St., San Francisco, Calif.
Finn Klingenberg, 567 5th St., Brooklyn, N. Y.
Daniel F. Mac Donald, 171 E. 94th St., New York, N. Y.
C. E. Mountain, Mandalay, Burma, India.
W. V. Tenzel, 3841 Cambridge Ave., Philadelphia, Pa.
S. C. Volney, 23 W. 49th St., New York, N. Y.

A. I. E. E. Section Activities

NEW DEVELOPMENTS IN ELECTROTHERMIC AND ELECTROCHEMISTRY

On the evening of Friday, March 22, the New York Section of the Institute will be addressed by Dr. Colin G. Fink, of Columbia University, on "New Developments in Electrothermics and Electrochemistry."

Dr. Fink will touch upon the developments in the electric furnace industries, emphasizing particularly the increasing importance of the induction furnace, the steady development of the arc furnace in the steel and ferro-alloys industries, and of the electric furnace in the chemical industries, notably phosphates and carbon bi-sulfide. Dr. Fink will then pass on to the fused electrolyte industries, pointing out the phenomenal growth of aluminum. The closely allied beryllium industry, just emerging from the laboratory stage will also be described. Particular emphasis will be placed upon changes in electroplating covering chromium plating. The electrochemistry of gases will also be touched upon. The talk will be accompanied by experiments. The meeting will be held in the Engineering Auditorium, 33 West 39th St., New York, N. Y. at 8.15 p. m.

FUTURE SECTION MEETINGS

Cleveland

Joint meeting with Case School of Applied Science Branch. March 19.

Communication. Electric League rooms, Hotel Statler. April 18.

Columbus

Electric Shovels Design, by Marion Steam Shovel Co., and

Electric versus Steam Shovels, by General Electric Co. Joint Dinner Meeting with Engineers' Club of Columbus. March 29.

Connecticut

Bridgeport, March 12.

Lehigh Valley

Making Sound Visible and Light Audible, by J. B. Taylor, and

Up-to-the-Minute on Anthracite, by Roy C. Haines. Sterling Hotel, Wilkes-Barre. March 22.

National Electric Code, by A. R. Small, and

Electrical Features of Mack Plant, by W. P. Mitchell. Americus Hotel, Allentown. April 19.

Madison

Talk by C. E. Skinner, Asst. Director of Engg., Westinghouse Electric & Mfg. Co. Dinner to precede address. April 16.

Niagara Frontier

Hydro-Electric Development of the Saluda River, by Wm. S. Murray, Engr. March 22.

Pittsburgh

Long Distance Toll Cable Transmission, by J. A. Cadwallader, Engr. of Transmission and Outside Plant, The Bell Telephone Co. of Pa. March 12.

Inspection trip to Cheat Haven, Pa.—the Lake Lynn Hydro-Electric Generating Station of West Penn Power Co. April 9.

Pittsfield

Electrotherapeutics. Tally-Ho, March 19.

St. Louis

March 20.
April 17.

Saskatchewan

Wiring Standards as Related to Fire and Life Hazards, by F. A. Cambridge, Consulting Engr., Western Canada Fire Association. March 22.

Seattle

Annual Joint Meeting of "Founder Societies." Address by C. E. Skinner, Asst. Director of Engineering, Westinghouse Electric & Mfg. Co. March 19.

Joint meeting with University of Washington Branch. Program under direction of Professor George L. Hoard, University of Washington. April 16.

Sharon

Development Work in the Telephone Field. April 2.

Toronto

The Relations of Electrical Engineers with the Public, by E. M. Ashworth, General Mgr., Toronto Hydro Electric System. The Section also expects to have present R. F. Schuchardt, President, A. I. E. E. March 8.

The Teletype Machine and the Automatic Telephone, by N. Knifht, Equipment Engr., Bell Telephone Co. March 22.

The Leaside Substation, by C. F. Publow, Engg. Dept., Hydro Electric Power Commission. April 12.

Utah

Manufacture of Insulators, by G. L. Wilder, Locke Insulator Corp. March 18.

Recent Developments in the Telephone Field, by H. W. Oddie, Transmission and Protection Engr., M. S. T. & T. Co. April 15.

Vancouver

Speaker from University of British Columbia. April 2.

Washington

The Diesel-Electric Locomotive, by N. W. Storer, Consulting Railway Engr., Westinghouse Electric & Mfg. Co. March 12.

The Engineer in Civic Affairs, by Prof. Dexter S. Kimball, Dean, College of Engineering, Cornell University. April 9.

MEETING OF NEW YORK SECTION DEVOTED TO INTERNATIONAL COMMUNICATION

At the meeting of the New York Section held on February 14, the following papers on various aspects of recent developments in international electrical communication were presented to an audience of about 650:

Short Waves and Long Waves in Transatlantic Radio Telephony, by Dr. Ralph Bown, Development & Research Dept., American Telephone and Telegraph Company.

South American Transcontinental Telephone Circuits Connecting Argentina, Uruguay and Chile, by F. A. Hubbard, Asst. Chief Engr., International Telephone and Telegraph Co.

Short Wave Technique Especially as Adapted to Facsimile, by Major R. H. Ranger, Design Engineer, Radio Corp. of America.

Construction and Laying of the Western Union Telegraph Company's 1928 Newfoundland-Azores Loaded Cable, by G. A. Randall, Western Union Telegraph Co.

ELECTRICAL DEVELOPMENTS OF 1928 REVIEWED BY ST. LOUIS SECTION

At a meeting of the St. Louis Section held on January 16, developments in various fields of electrical engineering during 1928 were reviewed by the presentation of the following program:

Communication, H. R. Fritz, General Transmission and Protection Engineer, Southwestern Bell Telephone Co.

Power Generation, H. O. Duetscher, Electrical Supt., Cahokia Power Plant, Union Electric Light & Power Co.

Electric Transportation, I. E. Cox, Railway Service Engineer, General Electric Co., St. Louis.

Power Distribution, M. R. Wallin, Construction Engineer, Union Electric Light & Power Co.

The presentation of the papers was followed by a general discussion in which there was much interest. The attendance was 62, and attendance prizes were awarded to A. A. Schuhler, E. L. Hough, E. J. Langley, and C. A. Loveless.

TWENTY-FIFTH ANNIVERSARY MEETING OF SEATTLE SECTION

A special program was presented at the meeting of the Seattle Section held on January 15 to commemorate the 25th anniversary of the formation of the Section.

A dinner was followed by brief talks by several of the early members of the Section, and a paper on *Development of Telephone Communication in the Northwest* was presented by O. C. Hoff, General Commercial Engineer, Pacific Telephone and Telegraph Company. The construction of the recently completed Cascade tunnel of the Great Northern Railway was shown by a reel of motion pictures. The attendance was 107.

JOINT MEETING HELD IN VIRGINIA

The Virginia Sections of the A. S. C. E. and A. S. M. E., Southern Virginia Section of the Institute, and the Engineers Club of Hampton Roads held their annual joint winter meeting in Norfolk, January 25 and 26, with a total attendance of 100, and the principal events are given below.

FRIDAY MORNING

J. S. A. Johnson, Chairman, Southern Virginia Section, A. S. M. E. Presiding.

The Organization and Functions of the National Advisory Committee for Aeronautics, by H. J. E. Reid, Engineer in Charge, N. A. C. A.

Equipment and Methods Used in Studying the Problems of Flight, by E. W. Miller, Chief, Aerodynamics Division, N. A. C. A.

LUNCHEON

J. H. Berry, President, Engineers Club of Hampton Roads, Presiding.

Address of Welcome, by Mr. Pleasants, speaking for Major Heth Tyler, Mayor of Norfolk.

History and Problems of Aeronautical Research, by T. A. Carroll, Chief Test Pilot, N. A. C. A.

Reminiscences of the Wright Brothers' Experiments at Kitty Hawk, by Capt. W. J. Tate.

FRIDAY AFTERNOON

R. B. H. Begg, President, Virginia Section, A. S. C. E., Presiding.

The Design and Development of Aircraft Power Plants, by Carlton Kemper, Power Plant Engr., N. A. C. A.

DINNER

Prof. W. S. Rodman, Chairman, Southern Virginia Section, A. I. E. E., Presiding.

Work of the Department of Commerce in Fostering Civil Aeronautics, by A. P. Taliaferro, Jr., Airport Specialist, Airport Section, U. S. Dept. of Commerce.

Air Mail Service, by Joseph Menth, Asst. Supt., Air Mail Service, U. S. Post Office Department.

Films—Air Corps, U. S. Army.

Films—*Kinematographic Studies in Aerodynamics*, prepared by Baron C. Shiba, Tokyo Imperial University.

SATURDAY

The party traveled by bus over the new James River Bridge to Langley Field where an inspection of the laboratories and equipment of the National Advisory Committee for Aeronautics was made, and remained at the field for luncheon.

The Southern Virginia Section, A. I. E. E., at a business meeting held on the first day of the joint meeting, elected the following officers to take office immediately: H. C. Leonard, Chairman; Cecil Gray, Secretary; S. W. Anderson and J. E. Jackson, members of executive committee.

PAST SECTION MEETINGS

Akron

Traffic Studies Being Made in Akron, by C. F. Fisher, Engr., City Planning Commission, Akron. Dinner. Joint meeting with A. S. M. E. and American Chemical Society. January 18. Attendance 23.

Control Equipment, by R. G. Lockert, Cutler-Hammer Mfg. Co. Moving pictures, showing the varied applications of electricity for industrial heating. February 8. Attendance 33.

Cleveland

Characteristics and Limitations of Insulating Materials for Power Cables, by E. W. Davis, Asst. Chief Engr., Simplex Wire and Cable Co. Brief talk by W. I. Middleton, Chief Engr., Simplex Wire and Cable Co. Dinner given by the Cleveland Electric Illuminating Co. for the speakers, officers, and invited guests. January 17. Attendance 80.

Dallas

Hydroelectric Developments and the Possibilities of Such Developments in South Texas, by G. W. Hamilton, Vice-President, Middle West Utilities Co. January 21. Attendance 196.

Denver

Electric Welding of Steel Buildings and Bridges, by F. P. McKibben, Consulting Engr., Schenectady, N. Y., and Black Gap, Pa. Illustrated by slides. Joint meeting with Colorado Section, A. S. C. E., preceded by a dinner. January 11. Attendance 250.

Electrical Transmission of Speech and Music, by W. G. Rubel, Transmission and Protection Engr., The Mountain States Tel. & Tel. Co. Slides and phonograph records. January 15. Attendance 75.

Electrical Development in Colorado in 1928, by F. F. McCammon, Asst. General Supt., Public Service Co. of Colorado. Part of Convention of Colorado Society of Engineers, held all day. January 19. Attendance 50.

Detroit-Ann Arbor

Banking of Transformers, by M. F. Mitschrich, Mgr., Moloney Electric Co. May 22. Attendance 75.

Golf tournament and picnic. June 16. Attendance 100.

Research Requirements of an Electrical Manufacturing Co., by S. M. Kintner, Mgr., Research Dept., Westinghouse Electric & Mfg. Co. A dinner preceded the meeting. January 15. Attendance 150.

Erie

Radio from the Broadcast Listener's Standpoint, by R. H. Manson, Chief Engr., Stromberg-Carlson Telephone Co. Slides. Mutual Telephone Co. served refreshments after meeting. January 15. Attendance 200.

Fort Wayne

The Engineers' Part in the Community Building, by J. B. Wiles, Mgr., Chamber of Commerce, and Industrial Commissioner of Fort Wayne. January 11. Attendance 40.

The Development of Television, by R. D. Kell, Radio Consulting Dept., General Electric Co. Motion pictures before meeting; refreshments after meeting. February 1. Attendance 125.

Indianapolis-Lafayette

Picture Transmission by Radio, by H. A. Iams, Westinghouse Electric & Mfg. Co. January 18. Attendance 275.

Kansas City

The Engineer in Civic Affairs, by Judge Darius Brown, and

Reyrolle Switchgear, by H. V. Nye, Engineer in Charge, Switchgear Division, Allis-Chalmers Mfg. Co. Slides. Refreshments. January 14. Attendance 50.

Lehigh Valley

Modern Physics, by Dr. Saul Dushman, Research Laboratories, General Electric Co. Slides. A dinner precided the meeting. Easton. December 14. Attendance 86.

Modern Power Transformers, by G. K. Kaiser, Transformer Engr., Westinghouse Electric & Mfg. Co. Lantern slides.

Effect of Insulators on Sags in Short Spans, by J. R. Stover, Metropolitan Edison Co. Brief talk by Vice-President J. L. Beaver, A. I. E. E. Reading, January 18. Attendance 82.

Los Angeles

Neon Lighting, by R. B. Anderson, Jr., Supt., Neon Electric Dept., Electrical Products Corp., and

Rebuilding of Power Plant No. 2, by H. C. Gardett, Elec. Engr. Bureau of Power and Light. Films and lantern slides. January 8. Attendance 150.

Lynn

The Weather Map and Weather Forecasting, by E. D. Rideout, Weather Forecaster, Station WEEI. Lantern slides. January 9. Attendance 110.

Inspection trip to new North Station and Boston Gardens Properties of the Boston and Maine Railroad. January 19. Attendance 325.

High Sensitivity Frequency Meters, by E. W. Clark;

Electrical Residence Heating, by P. C. Benedict, and

Portable Standards, by G. R. Sturtevant. Members of Section.

Measurements of Flow by Use of Electrical Instruments, by W. H. Pratt. Prepared for Winter Convention of A. I. E. E. January 23. Attendance 57.

Whaling, by Chester Scott Howland. Illustrated lecture. Ladies Night and dance. February 5. Attendance 850.

Madison

Three reels on "Electric Arc Welding of the Upper Carnegie Building."

Several of the Section members described experiences with arc welding. January 15. Attendance 37.

New York

Dinner at Lighting Institute of the Edison Lamp Works of the General Electric Co., Harrison, N. J., was followed by an address on "Latest Developments in Lighting," by A. L. Powell, Manager, Engineering Dept., Edison Lamp Works. Demonstrations of equipment for residence lighting, and various types of commercial lighting equipment were given, and a complete inspection of the Lighting Institute was made. December 14. Attendance 400.

National Broadcasting, by M. H. Aylesworth, President, National Broadcasting Co. Joint meeting with New York Electrical Society. February 6. Attendance 450.

Recent Developments in International Electrical Communication. (Complete report elsewhere in Section Activities dept.) February 14. Attendance 650.

Niagara Frontier

Safety, by H. C. Mawhinney, Foreman Electrician, Pennsylvania Railroad, and

Power Transformers, by H. L. Cole, Transformer Engr., Westinghouse Electric & Mfg. Co. Speaker entertained at dinner. November 16. Attendance 125.

Electrical Transmission of Personality, by L. S. O'Roark, Information Mgr., Bell Telephone Laboratories, Inc. Lantern slides and demonstrations. At a dinner preceding the meeting, speaker, officers of the Engineering Society of Buffalo, and invited guests were entertained. December 14. Attendance 175.

Philadelphia

The Photoelectric Cell and Its Uses in Communication, by M. B. Long, Educational Director, Bell Telephone Laboratories. Slides, moving pictures and talking moving pictures. Dinner preceded the meeting. January 14. Attendance 185.

Pittsfield

Transmission Line Stability, by R. H. Park and C. A. Nickle, General Electric Co. Speakers were entertained at dinner. January 15. Attendance 60.

Portland

Electric Welding of Steel Buildings and Bridges, by F. P. McKibben, Consulting Engr., Schenectady, N. Y., and Black Gap., Pa. Joint meeting with Oregon Technical Council and all Engineering Societies. January 29. Attendance 170.

Providence

Making Sound Visible and Light Audible, by J. B. Taylor, Consulting Engr., General Electric Co. Demonstrations. January 16. Attendance 250.

Rochester

Physical Requirements of High Quality Audio-Frequency Reproduction, by J. P. Maxfield, Manager of Engg. and Research, Victor Talking Machine Co. Slides and demonstrations. Joint meeting with Rochester Engineering Society and Rochester Section of Institute of Radio Engineers, preceded by a dinner in honor of the speaker. January 11. Attendance 156.

Centralized Traffic Control, by S. N. Wight, Commercial Engr., General Railway Signal Co. Four-reel motion picture. February 1. Attendance 78.

St. Louis

Resume of Electrical Development during 1928. (Complete report elsewhere in Section Activities dept. of this issue.) January 16. Attendance 62.

Saskatchewan

Grounding of Common Neutral Systems, by N. W. DuBois, Dist. Supt., Northern Light & Power Co. Brief address by L. A. Thornton, newly appointed Power Commissioner for the Province. February 7. Attendance 48.

Schenectady

Future Trends in Engineering Education, by Col. R. I. Rees, Asst. Vice-President, American Tel. & Tel. Co. January 11. Attendance 250.

Seattle

Engineering Features of A. C. Networks, by M. T. Crawford, Supt. of Distribution, Puget Sound Power & Light Co., and W. J. McKeen, Asst. Supt. of City Light Dept. December 18. Attendance 99.

Twenty-fifth Anniversary Meeting. (Complete report elsewhere in Section Activities dept. of this issue.) January 15. Attendance 107.

Sharon

Aviation Today, an Outline of Its Commercial, Military and Naval Aspects, by Lieut. Commander Bruce G. Leighton, Sales and Service Mgr., Wright Aeronautical Corp. Baron Shiba motion picture film on airplane research. January 15. Attendance 136.

Southern Virginia

Annual Joint Winter Meeting. (See complete report elsewhere in Section Activities dept.) January 25-26. Attendance 100.

Spokane

Reallocation of Broadcasting Stations, by T. W. MacLean, Radio Engr., Washington Water Power Co., and

Problems in Protective Relaying, by C. B. Carpenter, Relay Engr., Washington Water Power Co. Committee reports presented. January 25. Attendance 18.

Syracuse

Reception and Smoker. The Technology Club of Syracuse. January 7. Attendance 375.

Mercury Vapor Process for Power Generation, by Dr. Burt L. Newkirk, General Electric Research Laboratories. Slides. Discussion on cooperating with the Student Branch. Resolution was passed to submit to The Technology Club, recommending that the Club consider ways and means of furthering such relations. January 14. Attendance 250.

Toledo

Transformers, by H. B. Keath, Transformer Engineering Dept. Wagner Electric Corp. Slides. January 11. Attendance 35.

High-Tension Transmission Lines, by J. T. Kelly, Ohio Brass Co. February 8. Attendance 35.

Toronto

Electricity Applied to Agriculture, by J. W. Purcell, Asst. Engr., Hydro-Electric Power Comm. of Ont. January 11. Attendance 46.

Sir Joseph Flavelle, Chairman, Ontario Research Foundation, and Dr. Speakman, Director of the Foundation, spoke on the purposes and activities of that organization. Brief talks on the needs for research in the various fields were given by W. P. Dobson, electrical industry; Professor Parkin, mechanical engineering; Professor C. R. Young, civil engineering; H. Angus, heating and ventilating. The needs of mining engineering were discussed also. January 25. Attendance 175.

Utah

Electric Welding of Steel Buildings and Bridges, by F. P. McKibben, Consulting Engr., Schenectady, N. Y. and Black Gap, Pa. Slides. All the Engineering Societies in Salt Lake City invited to attend. January 14. Attendance 150.

Vancouver

Electric Welding of Steel Buildings and Bridges, by F. P. McKibben, Consulting Engr., Schenectady, N. Y. and Black Gap, Pa. Lantern slides. Joint meeting with Vancouver Branch, Engineering Institute of Canada, and members of Architectural Institute. February 4. Attendance 132.

Washington

Recent Developments in Electrochemistry, by G. W. Vinal, Physicist, Bureau of Standards. A dinner was held before the meeting. January 8. Attendance 74.

Worcester

Making Sound Visible and Light Audible, by J. B. Taylor, Consulting Engr., General Electric Co. January 15. Attendance 125.

A. I. E. E. Student Activities

STUDENT BRANCH ORGANIZED AT CORNELL UNIVERSITY

A Student Branch of the Institute was recently organized at Cornell University, and the following officers were elected: R. S. Milans, Chairman; A. B. Credle, Vice-Chairman; J. D. Russell, Secretary-Treasurer; W. G. Hoffman and J. W. Drummond, additional members of executive committee. Professor H. H. Race has been appointed Counselor. One very successful technical meeting has been held.

PAST BRANCH MEETINGS

University of Akron

Mechanical and Electrical Features of the New Automatic Telephones to be Installed in Akron, by Kenneth Baker, Alumnus; Ohio Bell Telephone Co. Mr. Clark gave a report on the Student Convention at Ohio State University. Four members gave talks on their work outside the university. January 25. Attendance 17.

Alabama Polytechnic Institute

Inspection trip to nearby power plants: Upper Tallassee Plant, Lower Tallassee Plant, both on the Tallapoosa River; and Jordan Dam Plant on the Coosa River. December 8. Attendance 45.

The Relation of the Engineer to His Society and the Equipment He Needs to Complete This Relationship, by Prof. Kirkely, English Dept. Messrs. Malone and Lyle, Alumni; Southern Bell Telephone Co., gave many helpful hints and related some of their past experiences. January 10. Attendance 42.

Electric Question Match, in which questions dealing with electric and magnetic theory were used. Six members on each side standing at close of match. January 31. Attendance 37.

University of Arkansas

Electrical Developments during the Year 1928, by James Basset, Student. January 24. Attendance 11.

Application of Electrical Processes to Chemistry, by A. S. Humphreys, Associate Professor of Chemistry. January 31. Attendance 31.

California Institute of Technology

Business Meeting. Discussion of plans for Los Angeles Section meeting to be held at California Institute of Technology on March 5, at which members of the Branch and the University of Southern California Branch will supply the program. January 30. Attendance 25.

Motion pictures, entitled "Electrical Transmission of Speech," "The Modern Magic," and "Desk-Stand Construction," were shown by E. P. Ledterman, Southern California Telephone Co. February 1. Attendance 225.

University of California

Business Meeting. The following officers were elected: Chairman, C. E. Cherry; Vice-Chairman, A. R. Morgan; Secretary, L. Levoy; Treasurer, B. Shaul; Members, Executive Committee, C. W. Mors and R. J. Streich. December 5. Attendance 13.

Hydraulic Development in Europe, by Prof. M. P. O'Brien. Slides. Reports of the Treasurer and various committees presented. January 23. Attendance 46.

Case School of Applied Science

Talk by Mr. Chapman, Experimental Engr., Lincoln Elec. Co. December 18. Attendance 24.

Television, by Dirk Schregardus, Transmission Engr., Ohio Bell Tel. Co. Illustrated with slides and moving pictures. Dinner. January 22. Attendance 23.

Clarkson College of Technology

Life and Work of Leonardo Da Vinci, by Prof. J. A. Ross, Head of the Dept. of Mechanical Engineering, and

The Failure of the St. Francis Dam, by Prof. W. J. Pharisee, Asst. Prof. of Civil Engineering. Illustrated. Motion pictures, entitled "Ties of Steel," "The Moulders," and "Making Sugar in Cuba." January 15. Attendance 36.

Cooper Union

Pyrometry, by L. Van Blerkom, 3rd yr. Night School. January 16. Attendance 35.

University of Colorado

Corona, by Prof. W. L. Cassell, Elec. Engg. Dept. January 23. Attendance 35.

University of Detroit

Joint Banquet with Aeronautical, Architectural, and Civil Engineering Societies, and Student Section of the Society of Automotive Engineers. Toastmaster, Harvey J. Campbell, Vice-President, Detroit Board of Commerce; Speakers, Judge Vincent M. Brennan, Circuit Court of Detroit; E. A. Batchelor, Sport Editor of the *Detroit Saturday Night*; C. F. Hirshfeld, Chief of Research, The Detroit Edison Co.; Subject, What is an Engineer? January 14. Attendance 470.

Georgia School of Technology

Reflections of an Engineer, by Joseph Dechovitz, Senior. Two reels of moving pictures, entitled "Revelations" and "King of the Rails," were shown. Joint meeting. January 25. Attendance 50.

Iowa State College

Business Meeting. Reports of committees presented. Appointment of smoker and donations committees. January 21. Attendance 20.

Electrical Engineers Smoker. Several short sketches by Prof. Ben. S. Willis. Prof. F. D. Paine gave a talk on "Opportunity." Refreshments. February 5. Attendance 150,

University of Kansas

Business Meeting. Election of officers for second semester. January 17. Attendance 41.

Lafayette College

E. Albert, Student, presented a paper entitled, *A Precision Regulator for Alternating Voltage*, written by H. M. Stoller and J. R. Power of the Bell Telephone Laboratories, Inc., and presented at the A. I. E. E. Winter Convention. February 9. Attendance 20.

Lehigh University

Visualizing Alternating Current Effects, with demonstration on the oscillograph, by L. K. Sowers, '29, and

Electrical Features of Pennsylvania R. R. Philadelphia Improvement, by J. L. Minick, Chief Asst. Elec. Engr. of Pa. R. R. Slides. Nomination of officers for next year. Refreshments. Short talk by Mr. Minick and humorous talk by Prof. N. S. Hibshman, Elec. Engg. Dept. February 8. Attendance 97.

Lewis Institute

The Modern Theory of Electrons, by A. J. Dempster, University of Chicago. Slides. January 11. Attendance 166.

University of Louisville

Prof. D. C. Jackson, Jr., Counselor, outlined the progress in Electrical and Mechanical Engineering. January 17. Attendance 14.

Progress Made in Science During Year 1928, by Robert Krajnak, Student, and

Lichtenberg Figures, by Samual Evans, Chairman,—from an article in November issue of A. I. E. E. Journal by Dr. C. E. Magnusson. January 31. Attendance 13.

University of Minnesota

Manufacture and Use of Capacitors for Improving Power Factor, by S. P. Bordeau, Electric Machinery Manufacturing Co. D. O. Brooks, General Electric Co., gave a demonstration of the capacitor motor. January 30. Attendance 60.

Mississippi A. & M. College

Four reels on "Electrical Measuring Instruments." Business meeting after film. January 30. Attendance 25.

University of Missouri

Commercial Transformer Tests, by Russell Bettis, Student, and

Diesel Engines in Small Generating Stations, by G. L. Crow, Student. January 14. Attendance 20.

Montana State College

The Fifth Annual Radio World's Fair, from *Radio News* for December 1928. Reader, Ted Rowe, Student;

What is Known about Glare, by P. S. Millar and S. McK. Gray, Electrical Testing Laboratories, New York, from *Electrical World* for November 24, 1928. Reader, Earl Rudberg, Student, and

Vacuum Tube is Heart of New Elevator Control System, from *General Electric Review* for December 1928. Reader, Otto Van Horn, Student. January 3. Attendance 55.

Ventilation of Railway Motors, by F. Paulsen, from *Electric Journal* for May, 1928. Reader, Sidney McArthur, Student, and

Determining Transmission Line Losses, by S. Murray Jones and Joel Tompkins, from *Electrical World* November 17, 1928. Reader Foster Buck, Student. January 10. Attendance 66.

Hydro-Electric Power Commission of Ontario, from Journal of A. I. E. E. for December 1928. Reader, Roy Newkirk, Student, and

Industry High Spots 1928-1929, from *Electrical World* for January 1929. Reader, Frank E. Hekkila, Student. January17. Attendance 64.

Interference Locator for Finding Power Line Leaks, from Citizens' Radio Call Book Magazine & Scientific Digest for January 1929. Reader, Len Robbins, Student, and

Radio Prospecting, from *Radio News* February 1928. Reader, C. Perleberg, Student. January 24. Attendance 69.

Electrolytic Zinc Production, by E. R. Fosdick, Elec. Engr., Sullivan Mining Co., from *Electrical World* for January 19, 1929. Reader Murray Davidson, Student;

Shattering the Atom, from Science and Invention for February 1929. Reader, Frank Brown, Student, and

High Frequencies for Color Television, by C. S. Gleason, from *Radio News* for January 1929. Reader, E. J. Christiansen, Student. January 31. Attendance 71.

Dance. February 1.

Rural Electrification, by J. C. Dow, Chief Engr., Great Falls Division, Montana Power Co. Three-reel picture on the rural electrification experiment conducted in a typical rural community at Red Wing, Minnesota. February 7. Attendance 88.

University of Nebraska

G. G. Young presented a report of research work on the "Neon Tube," by himself and associates, R. D. Reed, T. R. Lind and G. L. Hawks. Slides of gas-electric motor buses. The following officers were elected: Chairman, D. E. Schneider; Vice-Chairman, Elmer Koch; Secretary-Treasurer, H. G. Wiltse. January 23. Attendance 41.

Newark College of Engineering

Generator Ventilation, by W. K. Baer, Student. Chairman Hurd reported on the last Student Convention Committee meeting. January 21. Attendance 12.

Osiso, by C. A. Mead, Westinghouse Electric & Mfg. Co. Illustrated with slides and the Osiso itself. February 11. Attendance 35.

University of New Hampshire

Electrical Experiences with Price Brothers and Company, by T. W. Colby, Student, and

How and Why the Talkies, by T. Elliott, Student. January 12. Attendance 31.

A Visit to the Bellows Falls Power Plant, by J. K. Clark, Student, and

How and Why the Talkies, by H. Duquette, Student,—continuation of the paper presented at the previous meeting. January 19. Attendance 30.

Automatic Substations, by W. S. Bartlett, Student;

Trans-Atlantic Telephony, by A. W. Boyles, Student;

Rural Electrification, by B. C. Files, Student, and

Modern Trends in Electric Traction, by D. M. Googins, Student. January 26. Attendance 30.

Elevator Control, by P. F. Morton, Student;

Electricity Versus Oil Engines for Small Plants, by P. Nudd, Student, and

The Diverter-Pole Generator, by H. W. Smith, Student. February 2. Attendance 31.

North Carolina State College

Discussion of plans for the Engineering Fair to be held in March and assignments on the various exhibits. January 15. Attendance 21.

Northeastern University

International Electrotechnical Commission and Its Work, by Dr. A. E. Kennelly, Harvard University. Refreshments. January 15. Attendance 72.

University of Notre Dame

Research Work Being Done in the Field of Atoms and Electrons, by H. D. Sanborn, Publicity Representative, General Electric Co., Chicago. Motion picture, "Beyond the Microscope." Refreshments. January 14. Attendance 53.

Principle of Operation of the G. E. Electric Refrigerator, by F. M. Corliss, Adjustment and Claims Dept., General Electric Co., Cleveland. Slides, charts and working models. February 4. Attendance 80.

Ohio Northern University

The Diverter Pole Generator, by R. L. Gummo, Student. Plans for Engineers' Week discussed. January 24. Attendance 20.

Ohio State University

Airport Illumination, by D. C. Young, National Lamp Works, General Electric Co. January 25. Attendance 45.

Oregon State College

The Transatlantic Radiotelephone, by B. M. Mitchell, Senior. One-reel picture—"Driving the Longest Railroad Tunnel in the Western Hemisphere." January 14. Attendance 64.

Pennsylvania State College

Manufacture of Transformers, by Mr. Shive, Student, and

Manufacture of A. C. Machines, by Mr. Hamilton, Student. January 30. Attendance 30.

University of Pittsburgh

Research and Invention, by Thomas Spooner, Research Engr., Westinghouse Electric & Mfg. Co. Slides. Demonstrations of several types of apparatus developed recently. January 11. Attendance 68.

Batik Art Work, by N. J. Damaskin, Student, and

Heat Measuring Devices, by J. F. Reed, Student. January 18. Attendance 74.

A Short History of Steel, by D. N. Wylie, Student, and

The Purchase of Power by Electric Railroads, by G. E. Varga, Student. January 25. Attendance 69.

The Power and Transmission System of the Duquesne Light Co., by E. J. Cox, Duquesne Light Co. February 1. Attendance 59.

Purdue University

The Hot Element Cathode Ray Oscillograph, by R. H. George, Engineering Experiment Station, Purdue University. December 18. Attendance 60.

Film—"Electrical Indicating Instruments." January 9. Attendance 30.

Rhode Island State College

The Bureau of Standards, by James Randolph, Professor of Civil Engineering. Slides. January 9. Attendance 46.

The Radio Spectrum, by A. Z. Smith, Student. January 16. Attendance 41.

Airport Illumination, (General Electric Co. prepared lecture), by E. F. Ziochouski, Student. January 23. Attendance 16.

Rose Polytechnic Institute

Talk by F. P. Cox, '87, Manager, West Lynn Works, General Electric Co. January 18. Attendance 36.

Rutgers University

The Functioning of the Cathode Ray Oscillograph Tube, by Arnold Snowe, '30. Business session. January 14. Attendance 15.

University of Santa Clara

Features of Engineering Interest in a Modern A. C. Radio Receiver, by F. J. Somers, Student. Joint meeting with University of Santa Clara Engineering Society. January 29. Attendance 85.

Committee appointed to arrange for a joint meeting of the San Francisco Section with Student Branches of Stanford, California, and Santa Clara. Discussion of proposed new By-laws. January 30. Attendance 12.

University of South Carolina

Construction Problems Encountered in Building the San Pedro and the Calaveras Dams in California, by Allen Hazen. Talk by Mr. Lockridge. Joint meeting with A. S. C. E. Chapter. February 1. Attendance 60.

Business Meeting. February 6.

South Dakota State School of Mines

Business Meeting. Henry E. Sattler elected Chairman. February 8. Attendance 29.

University of South Dakota

Architectural Acoustics, by Willard Dickinson, Student. January 14. Attendance 14.

Films—"Driving the Longest Railroad Tunnel in the Western Hemisphere" and "New York's Newest Subway." January 23. Attendance 57.

Films—"The King of the Rails" and "The Panama Canal." January 31. Attendance 46.

University of Southern California

The Value of Student Papers in the A. I. E. E., by D. R. Stanfield, Chairman. Election of Officers. January 10. Attendance 35.

Stanford University

The Electrification of the Great Northern Railway, by C. R. Koch, graduate student. Films—"Driving the Longest Railroad Tunnel in the Western Hemisphere" (one-reel) and "Power Transformers" (two reels). January 15. Attendance 55.

Swarthmore College

Strain Gauges, Why and Where, by C. B. Adleman, Student, and

New Governor Design for a Metz Engine, by J. D. Egleson, Student. January 17. Attendance 25.

Syracuse University

Talking Movies, by Mr. Nellis, Student, and

The Duplex Transmission over a Single Pair of Wires, by Mr. Noxon, Student. November 27. Attendance 22.

Variable Speed Drives for Steel Mills, by Mr. Ridgeway, Student. December 4. Attendance 22.

Panel Type of Machine Switching, by Mr. Ott, Student, and

Recent Lightning Investigations, by Mr. Rosti, Student. December 11. Attendance 22.

Communication over Power Lines, by Mr. Seifert. January 8. Attendance 22.

Cosmic Rays, by Mr. Warntz, Student, and

Atomic Hydrogen Torch, by Mr. Zogby, Student. January 15. Attendance 22.

Texas A. & M. College

Transatlantic Radio Communication, by C. P. Sweeney, Student. Film—"The Conowingo Power Plant." February 8. Attendance 65.

University of Texas

Meter Inspection in the State of Texas, by W. T. Henrichson, '29 January 10. Attendance 16.

Business Meeting. The following officers were elected: President, L. R. Bagwell; Vice-President, W. V. Sippola; Secretary-Treasurer, C. B. Norris; Secretary, C. L. Jeffers. January 24. Attendance 8.

University of Utah

Circuit Breakers, by F. Gowens, Student. January 15. Attendance 9.

D. C. Motor Starting Control, by C. Z. Parker, Student, and

A. C. Motor Starting and Automatic Control Apparatus, by G. Littlefield, Student. January 28. Attendance 20.

University of Vermont

Films—"Television" (one reel) and "The Manufacture of Single Ridge Insulated Wire" (three reels). January 8. Attendance 50.

Virginia Polytechnic Institute

Freaks in Radio Transmission, by J. P. Shanklin, Student. January 28. Attendance 21.

Film—"Manufacture of Okonite Insulated Wire and Cable." February 4. Attendance 100.

University of Virginia

The How of the Talkies, by T. Davis, Student;

The Diverter Pole Generator, by G. G. Quarles, Student, and

Forces on Magnetically Shielded Conductors, by H. G. Seifried, Student. Report of last Section meeting by Prof. W. S. Rodman, Counselor. January 31. Attendance 14.

Washington State College

Prof. R. D. Sloan, Counselor, gave a talk on the Pacific Coast Convention and urged the juniors to present papers for competition. Three-reel film of the Okonite Manufacturing Company was shown. October 31. Attendance 29.

Electric Ship Propulsion, by Prof. R. D. Sloan, Counselor. November 14. Attendance 32.

Carrier Current Telephony, by Raymond Dennis. December 5. Attendance 20.

Municipal Fire Alarms, by Clyde Wood, Student. December 12. Attendance 26.

Talk by J. McKenna, who was a trouble shooter for the electrical apparatus in the building of the Cascade Tunnel. January 9. Attendance 25.

Washington University

Lighting Plans for the St. Louis Municipal Auditorium, by H. A. Brandenburger, Asst. to Ralph Toensfeldt, Consulting Engr. for the St. Louis Municipal Auditorium. Dinner preceded the meeting. December 13. Attendance 52.

University of Washington

Engineering Problems in Hawaii, by M. T. Crawford, Supt. of Distribution, Puget Sound Power and Light Co. January 11. Attendance 57.

Gold Mining in Alaska, by J. P. Corcoras, Student. Discussion of prizes proposed for best papers and talks. January 18. Attendance 21.

Business Meeting. January 25. Attendance 18.

University of Wisconsin

Experiences in Visiting General Electric Company's Plants during the Summer, by Mr. Horsfall, '29. Business session. October 31. Attendance 52.

Worcester Polytechnic Institute

Making Sound Visible and Light Audible, by John B. Taylor, Consulting Engr. General Electric Co. Lecture and demonstration. Joint meeting with Worcester Section. January 15. Attendance 250.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, JANUARY 1-31, 1929

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

AIR NAVIGATION AND METEOROLOGY.

By Capt. Richard Duncan. N. Y., Koppel Publishing Co., 1928. 136 pp., illus., diagrs., 7 x 5 in., bound. $3.50.

A concise text on the use of maps and charts, the compass and other instruments in piloting aircraft, and on the rudiments of meteorology. The author confines himself to matters of interest to flyers.

ALKALINE ACCUMULATORS.

By J. T. Crennell and F. M. Lea. N. Y., Longmans, Green & Co. 1928. 132 pp., illus., diagrs., 8 x 5 in., cloth. $3.00.

An account of the construction, characteristics, and operation of alkaline storage batteries, such as the Edison, Gouin, Ionic, and Jungner cells. Emphasis is laid on those characteristics that differ from those of lead cells and on the advantages and disadvantages of the alkaline cell, while the fields are indicated in which they excel.

AMERICAN SEWERAGE PRACTISE, v. 1; Design of Sewers.

By Leonard Metcalf and Harrison P. Eddy. 2d edition. N. Y., McGraw-Hill Book Co., 1928. 759 pp., illus., diagrs., tables, 9 x 6 in., cloth. $7.00.

In the fourteen years that have elapsed since the first publication of this book, American practise in sewer design has become more uniform, methods of applying certain principles have improved, and much valuable information has accumulated. This careful revision of one of the best texts on the subject will therefore interest all sanitary engineers.

The new edition has been carefully revised by the surviving author, Mr. Eddy, with the assistance of various members of his firm. The material has undergone considerable rearrangement and rewriting, bringing it up to date, and keeping it in the first rank as a practical reference book.

CENTRALES ELECTRIQUES.

By F. Drouin. Paris, J.-B. Ballière et fils, 1928. 602 pp., illus., diagrs., 9 x 6 in., paper. 85 fr.

A comprehensive survey of electric power plant practise, as exemplified by good modern types. The book is descriptive in nature and covers all important topics.

DER EINFLUSS DES COS φ AUF DIE TARIFGESTALTUNG DER ELEKTRIZITATSWERKE.

By Hans Nissel. Berlin, Julius Springer, 1928. 54 pp., illus., diagrs., tables, 9 x 6 in., paper. 4.50 r. m.

This monograph is a study of the principles underlying tariffs for electric power. In the first part the author describes the functions showing the relation of load factor to the capital cost and losses of an electric works, and from them derives a theoretically correct load-factor tariff.

As this theoretical tariff is not usable in practise, the author studies the tariffs actually used and ascertains which is the most desirable substitute for the theoretical one. He selects the apparent-power tariff as the most desirable.

ELECTRIC DRIVE PRACTISE.

By Gordon Fox. N. Y., McGraw-Hill Book Co., 1928. 421 pp., illus., diagrs., tables. 8 x 6 in., cloth. $3.50.

Successful application of electric motors to machine driving requires, among other things, knowledge of the requirements of the machinery to be driven and consideration of every aspect of its motion that affects the drive. The present book is intended to give this information for those classes of machinery which are in common use in many industries. It discusses motor drives for blowers, compressors, pumps, cranes and hoists, elevators, mine hoists, machine tools and industrial traction. The elements of load are evaluated and the factors that affect the determination of the size of motor for each kind of machine are pointed out. The functions of the different machines, the laws governing their action, and their distinctive requirements are enumerated, assisting the reader to select the proper motor for any given purpose.

THE ELECTRIC WORD; the Rise of Radio.

By Paul Schubert. N. Y., Macmillan Company, 1928. 311 pp., 8 x 6 in., cloth. $2.50.

A history of the radio industry. The technical evolution of apparatus is given brief mention only, but there is an interesting and connected account of the development upon financial and commercial lines, and of the political and industrial struggles that have occurred.

ELEKTRISCHE SCHALTGERATE ANLASSER UND REGLER, bd. 1.

By Fritz Kesselring. Ber. u. Lpz., Walter de Gruyter & Co., 1928. 142 pp., illus., diagrs., 6 x 4 in., cloth. 1.50 r. m.

Presents the theoretical principles underlying the design of switchgear in concise fashion, showing how the important formulas are derived and how to apply them in practise. A convenient summary of the necessary data.

FROM MAGIC TO SCIENCE; Essays on the Scientific Twilight.

By Charles Singer. N. Y., Boni & Liveright, 1928. 253 pp., illus., plates, 10 x 6 in., cloth. $7.50.

This handsomely printed volume contains seven essays by Dr. Singer, which have appeared in various previous publications, but which are now presented in revised form as contributions to the history of science. The author's object is to trace the slow decline of the observational sciences from the intellectual efficiency of classical antiquity and the earliest steps in the recovery.

The first essay gives a picture of science under the Roman Empire. Succeeding chapters trace the rapid deterioration of ancient science into magic and the beginnings of the redevelopment of scientific thought and method. Dr. Singer's study ends with the twelfth century.

FUNCTIONS OF REAL VARIABLES.

By E. J. Townsend. N. Y., Henry Holt & Co., 1928. 405 pp., 10 x 6 in., cloth. $5.00.

This text-book is based upon the course given at the University of Illinois, and is a companion book to the author's work on complex variables. It presupposes a training in the usual undergraduate course in mathematics and discusses those topics that will give the student a better grasp and understanding of the fundamental principles of the calculus of real variables, and some knowledge of recent developments of the subject.

THE GREAT CHEMISTS.

By Eric John Holmyard. Lond., Methuen & Co., 1928. 138 pp., 7 x 4 in., cloth. 3/6.

Dr. Holmyard describes the development of chemistry by considering the lives and works of its great exponents. Starting with Geber, he traces the gradual evolution of the main ideas and fruitful theories of the science down to those held today. His little book is well adapted to give the general reader an outline of the history of the subject.

THE HANDWRITING OF THE WALL; a chemist's interpretation.

By Arthur D. Little. Boston, Little, Brown & Co., 1928. 287 pp., 8 x 5 in., cloth. $2.50.

A collection of essays and speeches by an eminent chemical engineer. The central themes running through them are the debt of industry to chemistry and the dependence of continued industrial progress upon systematic scientific research. Dr. Little illustrates his views by many striking examples.

DIE HEBEZEUGE, bd 2; FORDERMITTEL IM BETRIEB.

By G. Tafel. Ber. u. Lpz., Walter de Gruyter & Co., 1928. 143 pp., illus., 6 x 4 in., cloth. 1,50 r. m.

A useful little summary of information on hoisting and conveying machinery. Attention is called to all existing types, the advantages and disadvantages of each are pointed out, and practical assistance in selecting appropriate machinery for a given purpose is supplied.

DIE HEIZ—UND LUFTUNGSANLAGEN IN DEN VERSCHIEDENEN GEBAUDEARTEN.

By M. Hottinger and W. V. Gonzenbach. Berlin, Julius Springer, 1929. 191 pp., 10 x 7 in., paper. 8.50 r. m.

The first part of this book presents the hygenic principles which underly the proper construction of heating and ventilating plants. The second and larger part applies these principles to the practical problem as it arises in building for various purposes. This section, classified by types of buildings, gives an exhaustive summary of approved methods, with references to much literature, for heating and ventilating dwellings, office buildings, theaters, public buildings, stores, restaurants, churches, baths, prisons, factories, etc.

INDUSTRIAL CARBON.

By C. L. Mantell. N. Y., D. Van Nostrand Co., 1928. (Industrial Chemical Monographs). 410 pp., illus., tables, 9 x 6 in., cloth. $4.50.

In addition to its use as fuel, carbon has many uses in industry. Diamonds are used for drilling, graphite for crucibles and other refractory products, and as a lubricant. Carbon is also used as a pigment, a decolorizer and for a variety of electrical purposes.

The various technical uses of carbon, aside from its use for fuel, are described in the present book. The information on the preparation, properties and uses of carbon products contained in the work has only been available heretofore after search through widely scattered sources, Its collection obviates much labor and provides a convenient work of reference in a neglected field.

INDUSTRIEOFEN, Bd. 1; Grundlegende Theorien und Bauelemente

By W. Trinks. Berlin, V. D. I. Verlag, 1928. 347 pp., illus., diagrs., 8 x 6 in., cloth. 16.-r. m.

A German translation of the first volume of "Industrial Furnaces," published in English in 1923.

DIE INTERFEROMETRISCHE MESSUNG IM ULTRAMIKROSKOP SICHTBAR GEMACHTER TEILCHEN VON 200 M U DURCHMESSER.

By O. von Baeyer u. U. Gerhardt. (Fortschritte der Chemie, Physik und Physikalischen Chemie, bd. 20, heft 1, Series B). Berlin, Gebrüder Borntraeger, 1928. 23 pp., 10 x 6 in., paper. 2.80 r. m.

A summary of the development and present situation of the method, based largely upon the work of the authors.

MATERIALS HANDBOOK.

By George S. Brady. N. Y., McGraw-Hill Book Co., 1929. 428 pp.. 7 x 4 in., fabrikoid. $4.00.

A convenient little reference book on abrasives, metals and alloys, building materials, fibers, textiles, paints, chemicals, oils, minerals, and woods used in industry. The materials, arranged alphabetically, are briefly described, with some indications of their properties and uses. A valuable feature is the inclusion of many new proprietary alloys.

MESSUNG MECHANISCHER SCHWINGUNGEN.

By Hermann Steuding. Berlin, V. D. I. Verlag, 1928. 500 pp., illus., 8 x 6 in., cloth. 28.-r. m.

This book obtained the prize offered in 1925 by the Verein Deutscher Ingenieure for the best critical investigation of methods and apparatus for measuring mechanical vibration. It is a convenient and thorough review both of the literature on the subject and of the methods and apparatus in practical use.

After an interesting classification of methods and apparatus from the viewpoints of physical principles and applications. the author first considers seismometry. The general theory of apparatus for measuring vibration is then discussed and criteria established for judging it. In the following chapters the individual methods, arranged by their uses, are reviewed. The fields considered are biology and physiology, varying stresses in structures and machines, acoustics, periodic vibrations in machinery, and indicators for engines. A valuable bibliography of over fourteen hundred references is included.

NOMOGRAPHIE.

By M. Fréchet and H. Roullet. Paris, Armand Colin, 1928. 208 pp., diagrs., 7 x 5 in., paper. 9 fr.

A beginner's manual on the construction and use of nomographs. The book explains the principles clearly and shows how they may be applied in practise. The joint work of a mathematician and an engineer.

PHOTOMICROGRAPHS OF IRON AND STEEL.

By Everett L. Reed. N. Y., John Wiley & Sons, 1929. 253 pp., illus., tables, 9 x 6 in., cloth. $4.00.

This book contains over two hundred photomicrographs of iron and steel, some of which have been subjected to mechanical and thermal treatments according to standard practises, the heat treatments having generally been those recommended by the Society of Automotive Engineers. The collection is useful for reference purposes to producers and users of steel.

TELEVISION.

By Alfred Dinsdale. London, Television Press, 1928. 180 pp., illus., ports., 7 x 5 in., cloth. 5s.

This book brings together the scattered information on television, which is usually not easily accessible. The book is especially detailed on the work of Mr. J. L. Baird, whose achievements are very fully set forth, but attention is also paid to those of other investigators and to past endeavors in this field. The account is written in non-technical language.

THEORY OF LIGHT.

By Thomas Preston. 5th edition, edited by Alfred W. Porter. Lond. & N. Y., Macmillan Company, 1928. 643 pp., 9 x 6 in., cloth. $8.00.

A new edition of a well-known text-book, carefully revised and brought up to date. The book is intended for students beyond the elementary grade with some knowledge of higher mathematics. To such readers it offers a connected account of the most important researches of former times which will enable him to study recent original investigations and theories.

THEORY OF PROBABILITY.

By William Burnside. Cambridge, Eng., University Press [& N. Y., Macmillan Co.], 1928. 106 pp., 9 x 6 in., cloth. $3.50.

This small volume represents a manuscript which Professor Burnside has practically completed before his death and which is now published by the Cambridge University Press. Professor Burnside's interest in the subject apparently was awakened during his study of military questions during the World War. As his interest grew, he ultimately set himself to make a systematic account of the theory of probability as it presented itself to him.

Among the topics are direct and indirect methods of calculating probabilities, methods of approximation, the probability of causes, probabilities connected with geometrical causes, the theory of errors, and Gauss's law.

DER ZUNDVERZUG BEI FLUSSIGEN BRENNSTOFFEN.

By Richard Hartner-Seberich. (Forschungsarbeiten, heft 299). Berlin, V. D. I. Verlag, 1928. 23 pp., illus., diagrs., 12 x 9 in., paper. 3.75 r. m.

An experimental and analytical study of the time lag of ignition in engines using heavy oil fuel. Experimentally, the author investigates the influence of such factors as initial temperature, initial pressure and air motion on the lag. Experimental results indicated that the laws of heat transference determine the magnitude of the lag, so the author proceeds to determine mathematically the transfer of heat from the air to the fuel oil and the part played by vaporization.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary: temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

MECHANICAL OR ELECTRICAL ENGINEER, 30-35, with thorough knowledge of machine and electrical design to take charge of hoist department. Must have had experience in the design of hoist automatic machine tools, or other work of this nature. Apply by letter giving age, education and experience. Location, Pennsylvania. X-7250.

ELECTRICAL ENGINEER, capable, with designing and experimental department experience. Opportunity. Apply by letter. stating age, educational qualifications and experience. Location, Middle West. X-7236-C.

RECENT GRADUATES, for large industrial corporation. Apply by letter. Location, Middle West. X-7249-C.

ELECTRICAL ENGINEER, under 40, with European, education, as technical translator on salary basis with well-known manufacturer. Reading knowledge of technical German essential. French or some other language also desirable. Apply by letter stating age, education and experience. Salary $45-$50 a week. Location, New York State. X-6852

ELECTRICAL ENGINEER with 2 or 3 years' experience since graduation. General Electric or Westinghouse Test desirable; for testing and experimental work on motors and control apparatus with a large manufacturing company. Apply by letter. Location, New York City. X-7054.

EXECUTIVE ASSISTANT. Technical graduate, 15 years' experience, at present employed, desires position requiring engineering and executive ability. B-9551.

GRADUATE, 26, single, with B. S. in Electrical Engineering and three years' experience, testing electric meters, desires work in engineering with opportunity for advancement. Available immediately. Location, immaterial. C-5028.

MEN AVAILABLE

GRADUATE ELECTRICAL ENGINEER with twelve years' experience in the design, construction, and operation of utility power plants and distribution systems and sales of equipment, desires position as engineer or superintendent with utility, engineering or manufacturing organization. B-9480.

ELECTRICAL ENGINEER, 26, single, 1927 graduate, B. S. in E. E., desires permanent position with public utility or manufacturing company dealing in electrical apparatus; has had five years' practical experience. C-3667.

ENGINEER, college graduate, 1925 B. S., 25, married. Three years' experience with southern public utility; distribution, design and operation and engineering office routine; estimating, drafting surveying. Location, United States. Available at once C-5511.

ELECTRICAL ENGINEER, degrees E. E., M. E. E., registered engineer two states Radio Engineering; designed and supervised construction large broadcast station; also been assistant professor of physics and electrical engineering, southern university and professor of mathematics, two southern colleges; desires radio engineering work or position teaching physics, electrical engineering, mathematics in South or Latin America. C-5521.

SALES ENGINEER, having over 500 close contacts with mechanical, electrical, and signal departments of eastern railroads. Service with four roads. Excellent technical education, two degrees and proved sales experience of over 15 years. Not the professional entertainer type. B-7881.

ASSISTANT EXECUTIVE, 37, married, technically trained. Connections with large public utility, manufacturers, and industrial consultants on work of administrative and commercial research nature. Especially qualified as assistant to busy executive needing man with managerial ability. Well endorsed. East preferred. B-9122.

ELECTRICAL ENGINEER, 32, B. S. in E. E., 9 years' experience in electrical construction, telephone work, instruments, maintenance, including 3 years on electrical construction of subways. Past positions; journeyman, foreman, inspector, student engineer and draftsman. Desires permanent appointment with engineering concern or manufacturer in United States. C-5500.

ELECTRICAL ENGINEER, 38, married. Technical and business education. 18 years' experience including 1 year miscellaneous, 5 years testing, 5 years inspection, 1 year in charge experimental laboratory, 6 years specifications, development U. S. government; very wide variety types, sizes, makes a-c. and d-c. machinery, control gear, measuring instruments, transformers, miscellaneous apparatus. Now employed. C-5327.

ELECTRICAL ENGINEER, 27, married, desires position in application or sales of motors and motor control. Four years technical training. Seven years general engineering with manufacturing and utility companies. One year University instructor. Canada preferred. C-5524.

TO ALL ACTUAL AND POTENTIAL PURCHASERS OF FOREIGN ELECTRICAL PROPERTIES. Can investigate, appraise, purchase, put on paying basis and manage a property, group of properties, or number of groups. Have had broad experience in investigation, appraisal and managing electrical properties in several countries. C-4222.

POWER OR PLANT ENGINEER, 41, experienced U. S. and foreign steam, gas, hydraulic, electric power-plant construction and operation; also industrial and building maintenance. Now employed Mid-Northwest; desires good industrial or institutional connection. $4000 minimum. Specialty, creating economies in power manufacture and usage. C-987.

ELECTRICAL AND MECHANICAL ENGINEER, graduate, 29, married. Completed the Alexander Hamilton Modern Business Course. One year G. E. Test Course. Five years general utility and industrial equipment, machine design and development work. Desires position with progressive public utility or industrial concern. Now employed, available on reasonable notice. C-1068.

ELECTRICAL ENGINEER, college graduate, 25, single; 1½ years as research engineer on electric meters; 2 years drafting room experience on d-c. and a-c. motors. Now employed; two weeks' notice required. Prefer position in electrical engineering department, since analytically inclined. Location, East or Middle West. C-5493.

RADIO TUBE ENGINEER, E. E. Development, production, supervision, quality control experience. Capable of managing plant and men. Now in responsible position but would consider change. C-5567.

ELECTRICAL DESIGNER, 30, single, having nine years' experience with public utility and manufacturing companies on distribution, transmission and power plant design. Desires position with opportunity to advance to executive capacity. Prefer work with part time spent in field. Graduate in Electrical Engineering. • C-254.

ELECTRICAL ENGINEER, university graduate, 36. Wide knowledge of electrification including generation, substations, distribution, motor application, control, lighting, etc., as applied to mining, cement mills and other industries. Experience covers estimates, design and layout, construction and maintenance. Desires to correspond with large industrial concern requiring the services of a man of above qualifications B-9113.

ELECTRICAL ENGINEER, 37, technical graduate. Broad general experience including both production work and general engineering, covering construction, operating and consulting for steel mills, manufacturing plants and coal mines. At present employed. Desires perma nent position with opportunity for growth. Location preferred, Eastern Seaboard. Best references. B-5471.

FACTORY MANAGER, technical graduate, 37, married. Ten years' experience as development engineer, factory engineer and factory executive in charge of manufacture, in one of the largest electrical concerns in the East. Available in one month. C-5587.

GRADUATE ELECTRICAL ENGINEER, 29, single. General Electric Company 2½ years, including Test and one years research on automatic equipment; one year's experience on underground and overhead distribution. Desires position with industrial concern or public utility. Future prospects considered more important than initial salary. No preference as to location. C-3762.

EXECUTIVE ENGINEER, 15 years' engineering and business experience in responsible positions. Technical graduate, 39, married, available immediately. Prefer public utility management, but will consider any real opportunity. B-6449.

ELECTRICAL ENGINEER, 27, married, graduate of Bliss Electrical School; 7 years' experience in electrical construction, maintenance repair and test. Two years as assistant in charge of all electrical construction, maintenance and repair, including d-c. armature and a-c. stator rewinding. Now employed, available on reasonable notice. C-5548.

PHYSICIST, for responsible position in research or development, Ph. D., 37; 12 years' experience in theoretical and industrial physical research at Massachusetts Institute of Technology, Bureau of Standards and elsewhere, specializing in optical instruments, sound recording, thermodynamics, electrophysics, and mathematical physics. Has published numerous papers on researches. C-2588.

MANUFACTURERS' REPRESENTATIVE. Engineer desires to represent several manufacturers of electrical machinery and supplies in the state of Sao Paulo, Brazil. C-5592.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER, with 12 years' experience in design, construction and operation, with power company, oil refining and industrial plants; desires position as consulting or electrical engineer with engineering firm, construction company or industrial plant. C-5570.

ELECTRICAL-MECHANICAL ENGINEER, 44, single, 20 years' experience. Factory test, central station engineering and sales work. Public utility operating engineer, assistant superintendent and superintendent of construction, power and electric departments. Estimate and design work on stations, substations, relay systems and lines Electric specifications and mechanical field engineering for buildings. B-271.

ENGINEERING EXECUTIVE, now in charge of the engineering department of a large public utility wishes opportunity for greater responsibilities in a utility or industrial organization. Experience of 20 years includes the supervision of civil, mechanical and electrical projects and contact with industrial plants of all kinds. C-5580.

TECHNICAL GRADUATE in electrical engineering, 34, married, several years' experience in installation, construction and maintenance of power plants and substations; also a year as assistant chief of plant, capable in producing results. Versed in foreign languages. Location South or foreign preferred but all locations considered. References, present employer. C-2021.

GRADUATE ELECTRICAL ENGINEER, 42; General Electric Test; experience in valuation of public utility properties; design, inspection, supervision of installation of mechanical, electrical equipment or urban rapid transit lines; with large electric light, power company in charge of preparation of operating and property records of underground plant. Qualified as assistant to executive on administrative work. A-3550.

ENGINEERING EXECUTIVE, experienced in various engineering construction; large oil storage and water reservoirs; dam construction; waterworks and sewers; steel plants and refineries; railroad construction and reconstruction. Has handled more than twelve million dollars' worth of construction in the past five years. Tropical experience. B-9926.

TEACHER OF ELECTRICAL ENGINEERING, ten years successful classroom experience in public high schools, technical night schools and in college with grade of Assistant Professor. Summer work at General Electric, Westinghouse and with telephone companies. Thoroughly familiar with a-c. and d-c. class and laboratory programs. C-1599.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

APPLICATIONS FOT TRANSFER

The Board of Examiners, at its meeting of February 20, 1929, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

ARNOLD, HAROLD DeFOREST, Director of Research, Bell Telephone Laboratories, New York, N. Y.

BIEGLER, PHILIP S., Prof. of Elec. Engg., Acting Dean, University of Southern California, Los Angeles, Calif.

BUCKLEY, OLIVER E., Assistant Director of Research, Bell Telephone Laboratories, New York, N. Y.

CURTIS, LESLIE F., Chief Engineer, American Bosch Magneto Corp., Springfield, Mass.

DAWSON, WILLIAM F., Designing Engineer, Generator Section, General Electric Company, West Lynn, Mass

WILKINS, ROY, Consulting Engineer, Pacific Elec. Mfg. Corp., San Francisco, Calif.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before March 31, 1929.

Adams, J. E., American Tel. & Tel. Co., Boston, Mass.
Anderson, O. E., Commonwealth Edison Co., Chicago, Ill.
Arters, Edward T., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Arvidson, A. E., Commonwealth Edison Co., Chicago, Ill.
Bailey, J. W., Bell Tel. Laboratories, Inc., New York, N. Y.
Bain, J. R., Canadian Westinghouse Co., Hamilton, Ont., Can.
Baldwin, M. W., Bell Tel. Laboratories, Inc., New York, N. Y.
Barnard, M. M., Northern Texas Traction Co., Fort Worth, Tex.
Barr, N. K., Public Service Co. of No. Ill., Chicago, Ill.
Bell, A. A., General Electric Co., Philadelphia, Pa.
Bellia, B. F., New York Central Railroad, New York, N. Y.
Bergeson R., Commonwealth Edison Co., Chicago, Ill.
Bergstrom H., Commonwealth Edison Co., Chicago, Ill.
Bethel, R. L., Commonwealth Edison Co., Chicago, Ill.
Bishop, E., Electric Storage Battery Co., Philadelphia, Pa.
Blaskett, S. N., Elliott Co., Ridgway, Pa.
Brady, G. B., Oklahoma Gas & Elec. Co., Enid, Okla.
Broaddus, P. H., Commonwealth Edison Co., Chicago, Ill.
Brown, C. W., (Member), Conn. Power Co., New London, Conn.
Brown, E. G., U. S. Engineer Office, Montgomery, Ala.
Brumbach, R. S., Reading Co., Reading, Pa.
Brunner, J. U., (Member), Brown Boveri Elec. Corp., Camden, N. J.
Buchanan, W. L., Westinghouse Elec. & Mfg. Co., Kansas City, Mo.
Burgess, E. G., Rockland Light & Power Co., Middletown, N. Y.
Burgess, O. A., New York Edison Co., New York, N. Y.
Burtis, J. H., New York Edison Co., New York, N. Y.
Butler, F. W., Greer College, Chicago, Ill.
Campbell, R. E., Commonwealth Edison Co., Chicago, Ill.
Campbell, T. H., Stone & Webster, Seattle, Wash.
Cardell, R. A. H., Commonwealth Edison Co., Chicago, Ill.

Carlberg, C H., Commonwealth Edison Co., Chicago, Ill.
Clark, B. L., Western Electric Co., Kearny, N. J.
Cocks, S. H E., Puebla Tramway Lt. & Pr. Co., Puebla, Pue., Mexico
Colbath, F. G., Bell Tel. Laboratories, Inc., New York, N. Y.
Crisp, R. P., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Croskery, D. J., Hydro-Electric Pr. Comm. of Ont., Toronto, Ont., Can.
Curran, C. L., Public Service Co. of No. Ill., Waukegan, Ill.
Curtis, L. W., Bell Tel. Laboratories, Inc., New York, N. Y.
Dausman, R. H., Public Service Co. of No. Ill., Waukegan, Ill.
Davidson, J. F., Public Service Co. of No. Ill, Chicago, Ill.
Decino, A., Bell Tel. Laboratories, Inc., New York, N. Y.
De Giovanni, H., Commonwealth Edison Co., Chicago, Ill.
Deitrich, L. E., Pennsylvania Water & Power Co., Baltimore, Md.
Dimmler, A. F., Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Dresser, W. H., Commonwealth Edison Co., Chicago, Ill.
Elkins, E. N., Public Service Production Co., Newark, N. J.
Evans, N. H., Dept. of Commerce, U S. Gov't., Washington D. C.
Farber, V. O., Frank Adam Electric Co., Brooklyn, N Y.
Farrell, J. V., New York & Queens Elec. Lt. & Pr. Co, Flushing, N Y
Faust, C. H, Phila. Suburban-Counties Gas & Elec. Co., Norristown, Pa.
Feeley, J. B., Commonwealth Edison Co., Chicago, Ill.
Ferguson, A. C., Hydro-Electric Pr Comm. of Ont., Toronto, Ont., Can.
Ficke, J. H., Public Service Co. of No. Ill., Joliet, Ill.
Flodin, C. R., Jr., Commonwealth Edison Co., Chicago, Ill.
Forsythe, C., Locke Insulator Corp, Dallas, Tex.
Fynney, C. S., Price Bros. & Co., Ltd., Chutes AuxGalets, Ste. Anne de Chicoutini, Que., Can.
Gain, L. A., Magnavox Co., Oakland, Calif. (Applicant for re-election.)
Garmany, G. M., P O. Box 178, Brightwaters, N. Y.
Gilliam, C T., (Member), Central Power & Light Co., San Antonio, Tex.
Gorder, F. C., Colts Patent Fire Arms Mfg. Co., Baltimore, Md.
Gould, D. W., 842 Commonwealth Ave., Boston, Mass.
Grover, E. W., (Member), Commonwealth Edison Co, Chicago, Ill.
Hains, D L., Public Service Co of No. Ill., Waukegan, Ill.
Harrington, G. P., Public Service Co. of No. Ill., Joliet, Ill.
Hauser, A., Brown & Gaine, Inc., Chicago, Ill.
Haverlah, K. W., Commonwealth Edison Co., Chicago, Ill.
Heald, M., (Member), Thordarson Electric Mfg. Co., Chicago, Ill.
Hemmenway, D. L., Worcester Electric Light Co, Worcester, Mass.
Hendrickson, E. R., Public Service Co. of No. Ill., Chicago, Ill.
Henry, U. L., Commonwealth Edison Co., Chicago, Ill.
Hilgedick, W. C., Western Union Telegraph Co., Dallas, Tex.
Hill, C. F., (Member), Westinghouse Elec. & Mfg Co., East Pittsburgh, Pa.
Horst, H. C., (Member), Regan Safety Devices Co., Inc., Niagara Falls, N. Y.
Hupp, R. L., General Electric Co., Fort Wayne, Ind.
Hutchins, L. B., (Member), Commonwealth Edison Co., Chicago, Ill.
Hutchinson, C. L., Commonwealth Edison Co., Chicago, Ill.
Jensen, B H., Commonwealth Edison Co., Chicago, Ill.
Jenssen, J. C., Commonwealth Edison Co., Chicago, Ill.
Johanson, E A., Western Electric Co., Inc., Kearny, N. J.
Johnson, A. B., Public Service Co. of No. Ill., Chicago, Ill.
Johnson, H. W., New York Telephone Co., New York, N. Y.
Johnson, R. R., Philadelphia Electric Co., Philadelphia, Pa.
Johnson, W. H., Public Service Co. of No. Ill., Chicago, Ill.
Jolliffe, J. P., City of Tacoma, Tacoma, Wash.
Jones, E. O., General Electric Co., Lynn, Mass.
Joyce, R. W., Puget Sound Pr. & Lt Co., Seattle, Wash.
Karrer, L. E., Puget Sound Pr. & Lt. Co., Seattle, Wash.
Kennett, J. F, Commonwealth Edison Co., Chicago, Ill
Kiel, P. J., Commonwealth Edison Co., Chicago, Ill.
Kimber, R. L., (Member), Westinghouse Elec. & Mfg. Co, Buffalo, N. Y.
Kopsa, L. F., United Electric Lt. & Pr. Co., New York, N. Y.
Kuehni, H. P., General Electric Co., Schenectady, N. Y.
Kuhlen, A. R., Commonwealth Edison Co., Chicago, Ill.
La Fiandra, P., Berardini State Bank, New York, N. Y.
Leatherman, L. A., Bell Tel. Laboratories, Inc., New York, N. Y.
Lieb, F. E., Public Service Co. of No. Ill., Chicago, Ill.
Leinbach, J. B., Jr., Pennsylvania Electric Co., Punxsutawney, Pa.
Libeck, M. C., Commonwealth Edison Co., Chicago, Ill.
Lindauer, E R., Elliott Co., Ridgway, Pa
Lindgreen, G. O. R., Commonwealth Edison Co., Chicago, Ill.
Lockwood, L. E., Public Service Co. of No. Ill., Streator, Ill.
Long, F. C., Western Electric Co., Kearny, N. J.
Loughlin, W. D., (Member), Radio Frequency Laboratories, Inc., Boonton, N. J.
Markley, F. R., Sun Oil Co., New York, N. Y. (Applicant for re-election.)
Martin, B. H., Public Service Dept., City of Glendale, Glendale, Calif.
Martin, C. A., Jr., N. J. Bell Tel. Co., Newark, N. J.
McArn, D. G., (Member), Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
McCall, D. B., General Electric Co., Pittsfield, Mass.
McClain, F. H., (Member), Iowa State College, Ames, Iowa
McConnell, E. S., American Brass Co., Waterbury, Conn.
McFarland, D. E., Jr., Public Service Elec. & Gas Co., Paterson, N. J.
Meyer, D. C., (Member), Bell Tel. Laboratories, Inc., New York, N. Y.
Michelis, R. P., Link-Belt Co., Chicago, Ill.
Miller, C. E., Commonwealth Edison Co., Chicago, Ill.
Moil, L. A., Reading Co., Reading, Pa.
Montague, J. A., Public Service Elec. & Gas Co., Jersey City, N. J.
Montbriand, B., Dominion Electric Power Ltd., Regina, Sask., Can.
Mueller, G. V., Purdue University, W. Lafayette, Ind.
Nagle, E. G., Pennsylvania Pr. & Lt. Co., Allentown, Pa.
Nagley, D. D., Commonwealth Edison Co., Chicago, Ill.
Nass, V. W., Commonwealth Edison Co., Chicago, Ill.
Nathanson, M., Can. Westinghouse Co., Hamilton, Ont, Can.
Nielsen, A. H., Public Service Co. of No. Ill., Joliet, Ill.
Northrop, R. O., Globar Corp., Niagara Falls, N. Y.
O'Brien, J. J., New England Power Co., Boston, Mass.
Otto, G. E., Westchester Lighting Co., New Rochelle, N. Y.
Palmer, R. T., Bell Tel. Laboratories, Inc., New York, N. Y.
Pearson, R. T., Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Perry, R., Commonwealth Edison Co., Chicago, Ill.
Peters, G. H., New York Edison Co., New York, N. Y.
Peterson, L. E., University of Minnesota, Minneapolis, Minn.
Peterson, M. M., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Petry, G. F., Amrad Corp., Boston, Mass.
Platt, F. L., Westinghouse Elec. & Mfg Co., Cincinnati, Ohio
Rackett, R. P., Commonwealth Edison Co., Chicago, Ill.
Rauscher, P. F., Public Service Co. of No. Ill., Waukegan, Ill
Raush, J., Jr., Commonwealth Edison Co., Chicago, Ill.
Regnier, L. A., Walker St., Lenox, Mass.
Richards, H. J., Electrical Research Products, Inc., Philadelphia, Pa.
Riepen, P., Takamine Corp., Long Island City, N. Y.
Rona, J., Pullman Free School of Manual Training, Chicago, Ill.
Rookstool, I. A., Commonwealth Utilities Corp., Limon, Colo.
Rumsey, W. W., (Member), Randolph Perkins, Chicago, Ill.
Sandelin, U. E., Tri-State College, Angola, Ind.
Schaibly, H. M., Commonwealth Edison Co., Chicago, Ill.
Schmidt, W. C., Consumers Power Co., Jackson, Mich.
Schweer, F. W., Newbery Electric Corp., Los Angeles, Calif.
Scott, T. W. A., Public Service Co. of No. Ill., Chicago, Ill.
Seelig, M. A., Commonwealth Edison Co., Chicago, Ill.
Sheekman, H. Z., Commonwealth Edison Co., Chicago, Ill.
Sicari, D., 500 Riverside Drive, New York, N. Y.
Sinnigson, G. A., Southwestern Bell Tel. Co., Lubbock, Tex.
Smith, A. C., Commonwealth Edison Co., Chicago, Ill.
Smith, L. L., Public Service Co. of No. Ill., Chicago, Ill.
Snyder, R. J., Public Service Co. of No. Ill., Waukegan, Ill.
Soderberg, A. O., Commonwealth Edison Co., Chicago, Ill.
Somerville, J. M., Canadian Porcelain Co., Ltd., Hamilton, Ont., Can.
Stone, V. L., Commonwealth Edison Co., Chicago, Ill.
Story, K. J., Commonwealth Edison Co., Chicago, Ill.
Stroup, C. L., Public Service Co. of No. Ill., Chicago, Ill.
Taubert, W. H., R. W. Lillie Co., New York, N. Y.
Taylor, G. Y., Public Service Co. of No. Ill., Waukegan, Ill.
Thostesen, I., Commonwealth Edison Co., Chicago, Ill.
Tietze, H. W., Public Service Elec. & Gas Co., Newark, N. J.
Titland, T. T., New York Edison Co., New York, N. Y.
Tornstrand, K. G., Commonwealth Edison Co., Chicago, Ill.

Trissal, J. M., Illinois Central Railroad Co., Chicago, Ill.
Ungrodt, A. L., Commonwealth Edison Co., Chicago, Ill.
Valentine, F., Westinghouse Elec. & Mfg. Co., Springfield, Mass.
Von Voigtlander, F., American Tel. & Tel. Co., Cleveland, Ohio
Wade, J. B., Layne & Bowler Corp., Los Angeles, Calif.
Wadia, R. D., United Electric Light & Power Co., New York, N. Y.
Walterstrom, W. K., Commonwealth Edison Co., Chicago, Ill.
Warner, E. S., Commonwealth Edison Co., Chicago, Ill.
Weaver, W. E., University of Toronto, Toronto, Ont., Can.
Webb, R. L., General Electric Co., Philadelphia, Pa.
Weiss, A. A., (Member), Tennessee Copper Co., Copperhill, Tenn.
White, S. H., General Electric Co., Schenectady, N. Y.
Whitlow, G. S., General Electric Co, St. Louis, Mo.
Wiederkehr, M. H., Allis Chalmers Mfg. Co.; Pittsburgh Transformer Co., Pittsburgh, Pa.
Winter, J., Gannon-Ward Systems, Erie, Pa.
Woldsund, S., 92 Columbia Heights, Brooklyn, N. Y.
Woodward, H. M, (Member), Southern Bell Tel. & Tel. Co., Birmingham, Ala.
Wright, E. A., Gulf Production Co., Goose Creek, Tex.
Wright, R. C., Board of Water & Light, City of Lansing, Lansing, Mich.
Young, Lottye E., (Miss), Coleman Lamp & Stove Co., Wichita, Kans.
Zink, H H, Commonwealth Edison Co., Chicago, Ill
Zumbusch, F. M., General Electric Co., Pittsfield, Mass.
Total 188.

Foreign

Goldsman, J. L., Consulting Radio Engr., Kingsway, London, W. C. 2, Eng. (Applicant for re-election.)
Joshi, U. P., Anglo Persian Oil Co., Ltd., Masjid-I-Sulaiman, South West Persia
Kallir, L., (Member), A. E. G., Union Elektrizitatsgesellschaft Wien, Austria
Kemp, L. W., Chile Exploration Co., Chuquicamata, Chile, So. America
Kurogochi, T., Shibaura Engineering Works, Ltd., Tokyo, Japan
Longbottom, J., Merz & McLellan, Newcastle-upon-Tyne, Eng.
Mansell, E. W., Rio de Janeiro Tramway, Lt. & Pr Co., Rio de Janeiro, Brazil, So. America
Ramberg, W. G. C., Technische Hochschule, Muenchen, Germany
Williams, L. A., C. B. Hansen & Co., Marton Nth Island, N. Z.
Total 9.

LIST OF SECTIONS

Name	Chairman	Secretary
Akron	John Grotzinger	H. C. Paiste, No. Ohio Pr. & Lt. Co., Akron, Ohio
Atlanta	H. L. Wills	W. F. Bellinger, Elec. & Gas Bldg., Atlanta, Ga.
Baltimore	W.B.Kouwenhoven	R. T. Greer, Cons. Gas Elec. Lt. & Pr. Co., Lexington Bldg., Baltimore, Md.
Boston	H. B. Dwight	G. J. Crowdes, Simplex Wire & Cable Co., Sidney Street, Cambridge, Mass.
Chicago	P. B. Juhnke	T. G. Le Clair, Commonwealth Edison Co., Rm. 822, 72 W. Adams St., Chicago, Ill.
Cincinnati	R. C. Fryer	L. O. Dorfman, Westinghouse E. & M. Co., 3rd & Elm Sts., Cincinnati, Ohio
Cleveland	E. W. Henderson	P. D. Manbeck, National Carbon Co., Madison Ave. & West 117th St., Cleveland, Ohio
Columbus	W. E. Metzger	R. A. Brown, 87 E. Dunedin Road, Columbus, Ohio
Connecticut	E. J. Amberg	R. G. Warner, Yale Univ. 10 Hillhouse Ave., New Haven, Conn.

LIST OF SECTIONS—*Continued*

Name	Chairman	Secretary
Dallas	G. A. Mills	A. Chetham-Strode, Dallas Pr. & Lt. Co., Interurban Bldg., Dallas, Texas
Denver	L. N. McClellan	R. B. Bonney, Telephone Bldg., P. O. Box 960, Denver, Colo.
Detroit-Ann Arbor	A. H. Lovell	L. F. Hickernell, Stevens & Wood, Inc., Consumers Power Bldg., Jackson, Mich.
Erie	M. L. Elder	A. W. Wennerstrom, General Electric Co Erie, Pa
Fort Wayne	C. F. Beyer	J. F. Eitman, 1841 Broadway, Ft. Wayne, Ind.
Houston	C. A. Williamson	L. K. Del Homme, Houston Lighting & Power Co., Houston, Texas
Indianapolis-Laf.	Herbert Kessel	G. R. Anderson, 2060 Northwestern Ave., Fairbanks, Morse & Co., Indianapolis, Ind.
Ithaca	R. F. Chamberlain	H. H. Race, School of Elec. Engg., Cornell University, Ithaca, N. Y.
Kansas City	B. J. George	A. B. Covey, Southwestern Bell Tel. Co., Kansas City, Mo.
Lehigh Valley	H. D. Baldwin	E. F. Weaver, Pa. Pr. & Lt. Co., 901 Hamilton St., Allentown, Pa.
Los Angeles	H. L. Caldwell	N. B. Hinson, Southern Cal. Edison Co., 3rd and Broadway, Los Angeles, Calif.
Louisville	E. D. Wood	N. C. Pearcy, Louisville Gas & Electric Co., 311 W. Chestnut St., Louisville, Ky.
Lynn	Charles Skoglund	V. R. Holmgren, Turbine Engg. Dept., G. E. Co., Bldg. 64 G, Lynn, Mass.
Madison	L. J. Peters	L. C. Larson, Dept. of Elec. Engg., University of Wisconsin, Madison, Wisconsin
Mexico	P. M. McCullough	F. Aubert, 2 A de Queretaro 22, Mexico City, Mexico
Milwaukee	E. R. Stoekle	R. R. Knoerr, Engr., Knoerr & Fischer, 553 Milwaukee St., Milwaukee, Wis.
Minnesota	M. E. Todd	V. E. Engquist, Northern States Pr. Co., Rice & Atwater Streets, St. Paul, Minn.
Nebraska	C. D. Robison	L. F. Wood, Room 1319, Telephone Bldg., Omaha, Neb.
New York	R. H. Tapscott	H. S. Sheppard, Dept. of Dev. & Research, Amer. Tel. & Tel. Co., 195 Broadway, New York, N. Y.
Niagara Frontier	G. H. Calkins	E. P. Harder, Buffalo General Electric Co., 205 Electric Bldg., Buffalo, N. Y.
Oklahoma	C. V. Bullen	C. T. Almquist, Dept. of Elec Engg., Univ. of Oklahoma, Norman, Okla.
Panama		
Philadelphia	L. F. Deming	R. H. Silbert, Philadelphia Electric Co., 2301 Market St., Philadelphia, Pa.
Pittsburgh	H. E. Dyche	J. A. Cadwallader, The Bell Telephone Co. of Pa., 416 7th Ave., Pittsburgh, Pa.
Pittsfield	J. R. Rue	V. M. Montsinger, General Electric Co., Pittsfield, Mass.
Portland, Ore.	L. M. Moyer	H. H. Cake, Pacific State Elec. Co., 5th and Davis Streets, Portland, Ore.
Providence	A. E. Watson	F. W. Smith, Blackstone Valley Gas & Elec. Co., Pawtucket, R. I.
Rochester	H. E. Gordon	C. F. Estwick, c/o General Railway Signal Co., Rochester, N. Y.
St. Louis	C. P. Potter	E. G. McLagan, 2188 Railway Exchange Bldg., St. Louis, Mo.
San Francisco	B. D. Dexter	A. G. Jones, General Electric Co., 804 Russ Bldg., San Francisco, Calif.
Saskatchewan	E. W. Bull	S. R. Parker, 2460 Montague St., Regina, Sask., Canada
Schenectady	E. S. Lee	E. E. Johnson, Room 435, Bldg. No. 2, General Electric Co., Schenectady, N. Y.
Seattle	C. R. Wallis	Ray Rader, Puget Sound Pr. & Lt. Co., Seattle, Wash.
Sharon	H. B. West	J. B. Gibbs, Westinghouse Electric & Mfg. Co., Sharon, Pa.
Southern Virginia	H. C. Leonard	Cecil Gray, Westinghouse Electric & Mfg. Co., Richmond, Va.
Spokane	Bernhard Olsen	H. L. Vincent, General Electric Co., 402 Paulsen Bldg., Spokane, Wash.
Springfield, Mass.	J. F. Murray	B. V. K. French, Am. Bosch Magneto Corp., Springfield, Mass.
Syracuse	W. R. McCann	F. E. Verdin, 1206 Hills Bldg., Syracuse, N. Y.
Toledo	W. T. Lowery	Max Neuber, 1257 Fernwood Ave., Toledo, Ohio
Toronto	E. M. Wood	W. F. Sutherland, Toronto Hydro Elec. System, 225 Yonge St., Toronto, Ont., Canada
Urbana	J. K. Tuthill	M. A. Faucett, University of Illinois, 301-A Elec. Engg. Laboratory, Urbana, Ill.
Utah	C. B. Shipp	A. C. Kelm, 133 So. West Temple, St., Salt Lake City, Utah
Vancouver	C. W. Colvin	J. Teasdale, British Columbia Elec. Railway Co., Vancouver, B. C., Canada
Washington	L. D. Bliss	R.W.Cushing, Federal Pr. Comm., Interior Bldg., 18th & F Sts., N. W., Washington, D. C.
Worcester	A. F. Snow	F. B. Crosby, Morgan Const. Co., 15 Belmont St., Worcester, Mass.
Total 54.		

LIST OF BRANCHES

Name and Location	Chairman	Secretary	Counselor (Member of Faculty)
Akron, Municipal University of, Akron, Ohio	C. D. Tinley	G. E. Burkholder	J. T. Walther
Alabama Polytechnic Institute, Auburn, Ala	J. J. O'Rourke	C. E. Meyer	W. W. Hill
Alabama, University of, University, Ala			
Arizona, University of, Tucson, Ariz	J. H. Hopper	Harold Soliday	J. C. Clark
Arkansas, University of, Fayetteville, Ark	T. E. Peter	B. H. Dorman	W. B. Stelzner
Armour Institute of Technology, 3300 Federal St., Chicago, Ill	C. J. McDonald	J. E. Wack	D. P. Moreton
Brooklyn Polytechnic Institute, 99 Livingston St., Brooklyn, N. Y	H. F. Steen	F. J. Mullen	Robin Beach
Bucknell University, Lewisburg, Pa	R. E. Snauffer	J. E. Bridegum	W. K. Rhodes
California Institute of Technology, Pasadena, Calif	G. R. Crane	A. W. Dunn	R. W. Sorensen
California, University of, Berkeley, Calif	C. E. Cherry	L. G. Levoy, Jr.	T. C. McFarland
Carnegie Institute of Technology, Pittsburgh, Pa	G. M. Cooper	J. H. Ferrick	B. C. Dennison
Case School of Applied Science, Cleveland, Ohio	W. A. Thomas	J. O. Herbster	H. B. Dates
Catholic University of America, Washington, D. C			T. J. MacKavanaugh
Cincinnati, University of, Cincinnati, Ohio	C. E. Young	W. C. Osterbrock	W. C. Osterbrock
Clarkson College of Technology, Potsdam, N. Y	D. R. Carpenter	C. H. Joy	A. R. Powers
Clemson Agricultural College, Clemson College, S. C	Laird Anderson	J. F. Callaham	S. R. Rhodes
Colorado State Agricultural College, Fort Collins, Colo	G. W. Mitchel	D. P. Nohr	H. G. Jordan
Colorado, University of, Boulder, Colo	H. R. Arnold	E. E. Stoeckly	W. C. DuVall
Cooper Union, New York, N. Y	Wilfred Henschel	H. H. Reuter	N. L. Towle
Cornell University, Ithaca, N. Y	R. S. Milans	J. D. Russell	H. H. Race
Denver, University of, Denver, Colo	J. N. Petrie	D. S. Cooper	R. E. Nyswander
Detroit, University of, Detroit, Mich	E. T. Faur	Wm. F. Haldeman	H. O. Warner
Drexel Institute, Philadelphia, Pa	D. M. Way	C. W. Kenyon	E. O. Lange
Duke University, Durham, N. C	W. E. Cranford	C. W. Berglund, Jr.	W. J. Seeley
Florida, University of, Gainesville, Fla	A. W. Payne	N. J. Rogers	J. M. Weil
Georgia School of Technology, Atlanta, Ga	E. M. Burn	K. W. Mowry	
Idaho, University of, Moscow, Idaho	O. C. Mayer	K. P. Kenworthy	J. H. Johnson
Iowa State College, Ames, Iowa	R. R. Law	C. E. Rohrig	F. A. Fish
Iowa, State University of, Iowa City, Iowa	Drew MacDougal		
Kansas State College, Manhattan, Kansas	H. C. Lindberg	J. W. Schwanke	R. G. Kloeffler
Kansas, University of, Lawrence, Kans	Norvel Douglas		G. C. Shaad
Kentucky, University of, Lexington, Ky	C. W. Daniel	L. L. Massie	W. E. Freeman
Lafayette College, Easton, Pa	H. W. Lovett	C. W. Zook	Morland King
Lehigh University, Bethlehem, Pa	S. R. Van Blarcom	R. S. Taylor	J. L. Beaver
Lewis Institute, Chicago, Ill	A. Gaimari	Leo Weinshank	F. A. Rogers
Louisiana State University, Baton Rouge, La	J. C. Bice	J. J. Bridges, Jr.	M. B. Voorhies
Louisville, University of, Louisville, Ky	Samuel Evans	J. S. Overstreet	D. C. Jackson, Jr.
Maine, University of, Orono, Maine	A. V. Smith	G. A. Whittier	W. E. Barrows, Jr.
Marquette University, 1200 Sycamore St., Milwaukee, Wis	P. C. Neumann	W. E. Schmitz	J. F. H. Douglas
Massachusetts Institute of Technology, Cambridge, Mass	R. M. Durrett	F. O. Urban	W. H. Timbie

LIST OF BRANCHES—*Continued.*

Name and Location	Chairman	Secretary	Counselor (Member of Faculty)
Michigan State College, East Lansing, Mich	M. H. Blivin	W. G. Keck	M. M. Cory
Michigan, University of, Ann Arbor, Mich	W. R. Hough	H. L. Scofield	B. F. Bailey
Milwaukee, School of Engineering of, 163 East Wells St., Milwaukee, Wis	G. E. Henkel	T. J. Coleman, Jr.	J. D. Ball
Minnesota, University of, Minneapolis, Minn	C. L. Elliott	C. J. Johnston	J. H. Kuhlmann
Mississippi Agricultural & Mechanical College, A. & M. College, Miss	R. S. Kersh	L. L. Stokes	L. L. Patterson
Missouri School of Mines & Metallurgy, Rolla, Mo	F. B. Beatty	E. J. Gregory	I. H. Lovett
Missouri, University of, Columbia, Mo	G. L. Crow	C. B. Holt	M. P. Weinbach
Montana State College, Bozeman, Mont	J. M. Fjeld	G. E. West	J. A. Thaler
Nebraska, University of, Lincoln, Neb	D. E. Schneider	H. G. Wiltse	F. W. Norris
Nevada, University of, Reno, Nevada	Alden McCullom	A. B. Chace	S. G. Palmer
Newark College of Engineering, 367 High St., Newark, New Jersey	C. P. Hurd	W. R. Ackor	J. C. Peet
New Hampshire, University of, Durham, N. H	N. J. Pierce	M. W. Cummings	L. W. Hitchcock
New York, College of the City of, 139th St., & Convent Ave., New York, N. Y	Daniel Klatzko	Walter Broleen	Harry Baum
New York University, University Heights, New York, N. Y	G. A. Taylor	A. W. Schneider	J. L. Arnold
North Carolina State College, Raleigh, N. C	O. M. Carpenter	W. E. Moseley	R. S. Fouraker
North Carolina, University of, Chapel Hill, N. C	W. B. Sharp	E. T. Gross, Jr.	P. H. Daggett
North Dakota, University of, University Station, Grand Forks, N. D	J. K. Walsh	O. A. Aaker	D. R. Jenkins
Northeastern University, 316 Huntington Ave., Boston 17, Mass	R. W. Cleveland	H. F. Wilder	W. L. Smith
Notre Dame, University of, Notre Dame, Ind	J. J. Donahue	F. J. Weiss	J. A. Caparo
Ohio Northern University, Ada, Ohio	R. F. Rice	R. A. Lash	I. S. Campbell
Ohio State University, Columbus, O	R. H. Spry	G. W. Trout	F. C. Caldwell
Ohio University, Athens, O	Clarke Kenney	H. W. Giesecke	A. A. Atkinson
Oklahoma A. & M. College, Stillwater, Okla	E. L. Weathers	H. E. Bradford	Edwin Kurtz
Oklahoma, University of, Norman, Okla	C. K. Ittner	Le Roy Moffet, Jr.	F. G. Tappan
Oregon State College, Corvallis, Ore	Harry Loggan	A. W. Swingle	F. O. McMillan
Pennsylvania State College, State College, Pa	H. W. Bair	J. F. Houldin	L. A. Doggett
Pennsylvania, University of, Philadelphia, Pa	T. E. Manning	H. W. Brown, Jr.	C. D. Fawcett
Pittsburgh, University of, Pittsburgh, Pa	J. B. Luck	J. G. Hoop	H. E. Dyche
Princeton University, Princeton, N. J	W. V. G. Eakins	C. F. Nesslage	Malcolm MacLaren
Purdue University, Lafayette, Indiana	J. F. Nuner	P. C. Sandretto	A. N. Topping
Rensselaer Polytechnic Institute, Troy, N. Y	S. E. Benson	David Younger	F. M. Sebast
Rhode Island State College, Kingston, R. I	F. E. Caulfield	A. Z. Smith	Wm. Anderson
Rose Polytechnic Institute, Terre Haute, Ind	R. H. Dowen	G. P. Brosman	C. C. Knipmeyer
Rutgers University, New Brunswick, N. J	John Cost	H. M. Hobson	P. S. Creager
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South Carolina, University of, Columbia, S. C	W. E. Eargle	L. A. Griffith	T. F. Ball
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Wire Strippers.—Bulletin, 4 pp. Describes two models of "Perfection" wire strippers for removing insulation from solid, stranded tinsel, multi-conductor cable or wire up to one-half inch diameter. Weber Machine Corporation, 33 South Water Street, Rochester, N. Y.

Circuit Breakers.—Bulletin 580. Describes a new line of small, enclosed, air break circuit breakers, Type EAF. They are made in capacities of ½ ampere to 80 amperes; 250 volts, d-c. and 550 volts, a-c.; two and three pole; overload, undervoltage, time limit, free handle; all fully enclosed. Roller-Smith Company, 12 Park Place, New York.

Valve Control.—Bulletin, "Modern Valve Control Practise," 22 pp. Describes the Cutler-Hammer automatic valve control system. Illustrations show the use and installation of motor driven valves, grouped by applications in various industries. A feature is the operation of all valves throughout a plant by means of pushbuttons from a single centralized control board. Cutler-Hammer, Inc., 163-12th Street, Milwaukee, Wis.

Oil Circuit Breakers.—Bulletin 1804, 8 pp. Describes Westinghouse types O-31 and O-441 oil circuit breakers for either indoor or outdoor use in capacities from 600 to 2000 amperes at 37,000 volts. Bulletin 1812, 8 pp. Describes types G-22 and G-222 breakers for heavy-duty, alternating-current service for either indoor or outdoor use. They are made in 600 and 1200 ampere current carrying capacities at 73,000 volts. The breakers described in both bulletins are electrically operated. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Penn.

NOTES OF THE INDUSTRY

The Sangamo Electric Company, Springfield, Ill., has moved its New York office, for the past fifteen years in the Hudson Terminal Building, to the Chanin Building, 122 East 42nd Street. The service station will also be moved to 228 East 45th Street, convenient to the new office location.

The Lincoln Electric Company, Cleveland, Ohio, manufacturer of "Stable-Arc" welders and "Linc-Weld" motors, announces the appointment of C. M. Taylor as sales manager. He has been connected with the company since his graduation from Western Reserve University in 1916. He was previously vice-president and factory manager.

The Maring Wire Company, Muskegon, Mich., has added approximately 30,000 square feet of manufacturing space to its factory, making a total of 80,000 square feet. The addition is designed to house equipment necessary to take care of commitments on fine enameled wires and will increase annual production by 5,000,000 pounds of copper. Half of additional space will be available for production by March 15th and balance by May15th.

The Metropolitan Device Corporation, Brooklyn, N. Y., manufacturer of Murray protective devices, distribution equipment and Murray electric radiators, announces the appointment of William J. McIlvane as general sales manager. Mr. McIlvane comes to the Metropolitan Device Corporation from the Copperweld Steel Company, with whom he served as district sales manager in charge of sales east of the Mississippi River. Previously he was district manager of the W. N. Matthews Corporation in New York.

The Hanson-VanWinkle-Munning Co., Matawan, N. J., manufacturer of electroplating and polishing equipment and supplies, has announced the appointment of C. W. Yerger as sales manager. The step was necessary in order to enable E. N. Boice, secretary, who in addition to his other activities has been directing the sales of the company, to give full time to his regular executive duties. Mr. Yerger was previously eastern district manager of Cutler-Hammer, Inc., having been associated with this company since 1908.

New Motor Starter.—The Condit Electrical Manufacturing Corporation, Boston, announces the development of a new cross-the-line air motor starter to be known as Type A-30, for use with squirrel-cage induction motors up to 20 hp., 550 and 440 volts; 15 hp., 220 volts and 7½ hp., 110 volts. The new starter prevents arcing with its accompanying effects of gas and contact burning, exhaustive tests having shown there is only a spark when interrupting currents six to seven times its normal rating and relatively no contact burning or gas. Fifty thousand operations at twice normal current on circuits of 55% power factor at maximum rated voltage caused less deterioration than a few such duty cycles on similar rated existing devices.

New Fuseswitches.—The W. N. Matthews Corporation, St. Louis, manufacturer of electrical specialties since 1899, has announced a new line of Fuseswitches. The outstanding points claimed for this device are: safety to operator; no live parts on door of switch; genuine wet process porcelain housing; adjustable hanger; the patented Matthews double tube cartridge; no radio interference; flat surface pressure type contacts; inspection without interruption of service; readily converted to disconnecting switches; they use fast blowing Matthews Fuslinks. The 700 has a rating of 60 amperes, 2500/4400 Y volts; rupturing capacity 3000 amperes; dry flashover 43,500 volts; wet flashover 20,000 volts. The 800 has a rating of 60 amperes, 7500 volts; rupturing capacity 4000 amperes; dry flashover 48,000 volts; wet flashover 27,500 volts.

New Current Control.—The Electric Controller & Manufacturing Company, Cleveland, has announced a new development, time current control, using an acceleration relay operating on an entirely new principle. Every advantage of existing systems of acceleration is claimed for the time-current relay. On steel mill loads such as screw-downs, mill tables and other drives where fast operation means greater production, time-current control gives maximum output. On heavy loads, longer time up to two seconds per step is had automatically without any change in adjustment. On abnormal loads, forced acceleration gradually increases the torque until the motor eventually starts. This time-current control which embodies the new time-current acceleration relay also uses a new line of shunt contactors and a new plugging relay. With the new system it is claimed that it will be unnecessary to punish the motors, in order to get maximum production, during periods of abnormal load.

The Electrically Heated Home.—Homes and buildings in a half dozen cities are being successfully heated by a new electrical system this winter, according to Chester I. Hall, president of the Hall Electric Heating Company of Philadelphia. Mr. Hall developed this new method of heating while a research engineer of the General Electric Company, in charge of its experimental laboratory at Ft. Wayne, Ind. The method consists of heating large thermal storage tanks of water, using electric current only at night, when it can be obtained from the utility at the lowest cost, and releasing this stored heat within the home as required. The Hall heating system can be installed as a hot air, hot water, vapor or double-pipe system and may be arranged to supply the domestic hot water needs.

The Hall Electric Heating Company was formed a year ago. The General Electric Company, and associates, hold a substantial interest in the company and manufacture the control and electrical parts. The engineering, development and sales work of the Hall Company are carried on at its main office in Philadelphia.